FIRST GET-TOGETHER OF RESEARCH AND INDUSTRY

December 20 – 21, 1965

Research Utilization, Cooperation Between Research and Industry, Policies on Research & Development

WORKING GROUP 15

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH, NEW DELHI

Research Utilization, Cooperation Between Research and Industry, Policies on Research & Development

WORKING GROUP 15

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
NEW DELHI

Printed at Delhi Printers, 21 Daryaganj, Delhi 6

CONTENTS

CONTENTS

Organizing Research For Industry

S. K. SUBRAMANIAN
National Chemical Laboratory
Poona

Research and development activities directed towards national economy must be organized and managed. The aim of research management is to advance technology by means of an organization and the secondary objective is to operate the organization effectively. The basic principles of research management are discussed with particular reference to India. Without proper organization and time targeted team-work, based on clearly defined objectives, supported by suitable communication systems, and aided by other management tools, the return for the investment in research and development will be poor.

Today no one disputes the need for research and development, for unlike the frosting on a cake they have become critical elements of one's diet. Research in one form or the other is a must to sustain the growth of technology and there is a world-wide recognition that technology offers high standards of living and nations are convinced that the only hope of escaping poverty lies in modern technology.

Any discovery or invention of a new product or service or allied improvements in existing systems must be reduced to public practice and only when the idea becomes a commercial proposition, it enters the economic stream and becomes a part of the process of economic growth. Since the products have to be manufactured before they can be marketed, manufacturing industry is the pace setter in economic growth, essentially, because it is the sector wherein the rate of input of technology is highest.

In the overall realm of technology, the function of the research scientists is to seek and understand new experiences which the exploratory developer can utilize to create new devices and techniques. Of course the exploratory development is much older than scientific research and this is the field of the inventor. In the past the inventors used whatever knowledge they could find, some of it sound but most of it unsound, and as a consequence, invention was a haphazard game with chances of success slim. The modern exploratory development relies heavily on systematic knowledge and understanding. By creating a highly organized team attack, the element of chance has been reduced. The reduction of the time gap between a completion of a new development and its application, bears testimony to the success of this approach. The time gap between the demonstration of Newcomen's engine and the first rail road engine was roughly hundred years. Whereas less than three years after the Chicago

atomic pile, large scale atomic piles were operating and within ten years practical atomic fuel power plants were in action.

The selection of the course of action to be taken from a wide choice, is not made by the scientist or the inventor but by the entrepreneurs of the business, financial, military and political worlds. The introduction of a new commodity or a service into use by the public at large calls for a large sums of money and manpower investments. In addition, the promised performance of the new commodity or service must be realized with safety, reliability and ease of operation. In the absence of other compelling factors, its cost must be within the means of the potential users and must of course be favourable when compared with competing items designed to do the same job. Above all, the economic atmosphere must be such that the demand for the commodity will be large enough to justify the investment in it.

Thus, whether a new knowledge or development will be reduced to public practice depends on a number of factors: (i) The technological environment prevailing at that time, i.e., the sum total of all the know-hows, skills, techniques, tools, materials etc. readily available for producing or perfecting a new device or service, so that it can be presented to the using public in simple, reliable and economical form, (ii) The economic environment, i.e. the reduction to the public practice of a new development depends strongly on its ability to fulfil a need for which people not only wanted to pay but for which they could pay. The result has been intense efforts to reduce prices without apparent loss of performance and also a healthy technology has roused its economic environment to a point where standards of living are high and the ability to assimilate more technological development is correspondingly great, and (iii) Geopolitical environment, i.e. the military strategy, special political circumstances etc.; however, normally in non-military fields the economic environment is the important criterion.

Thus economic uplift of the country is directly related to technology and we cannot think of technology without the environment. Naturally the research and development activities intended for the economic uplift cannot be separated from the environment factors. For a successful conduct of modern research and development activities it is very essential that those responsible for planning and execution broaden their thinking to include these various factors.

Closely allied to this is the concept of research productivity, which like any other form of industrial activity can be progressively increased. Modern industrial research is a rather straightforward activity which has definite objectives to be established and examined. Research is important in its own right and one can scarcely put any precise money value for it. However, hard-earned money should go in quantity only to programmes and projects where the practical need has been demonstrated, where there is every likelihood of a financial return or failing that where some practical accomplishment can be made such as cure of a disease or production of a superior military weapon. Hence applied research should be planned and judged by its practical value.

Since the operation of applied research involves cost and time factors and calls for the cooperation of the intellectual and practical talents of men of varied fields, the need for organization sets in. The need for organization or management, which is the oldest of the arts and youngest

of the sciences, in any complex system need not be overstressed. Taking the example of the industrial enterprise, it can no longer be run solely on scientific knowledge, top engineering skills and patents alone. There is need for continuing growth and development and adaptation to a rapid rate of change. Growth depends on the ability of management. Probably it always did, but there is a new need for more aggressive attitude and more positive action. Everything which makes for growth, demands the co-ordination by management of the activities of several departments. During the earlier period the machine was the centre of the system and the new phenomenon is that when enterprises grow larger and larger, organization itself plays an increasingly important part.

The modern management school is making extremely important contributions by attacking objectively the complicated problems that arise when human beings cooperated in a system.

It is questioning the dogmas, studying and systematizing the methods of successful practitioners and evolving new techniques and broadening our basis of understanding. In a simple and static society faults of organization or management are relatively unimportant and they get ironed out by experience. In a modern and progressive society, these faults can ultimately lead to decadence.

The birth of research management can be allied to the development of education. With the growth of education, the need for a movement on how to teach rather than what to teach arose. The aim of research management is to advance technology by means of an organization and the secondary objective is to operate the organization effectively. Of course, in research, many of the management practices successfully employed ordinarily cannot be readily applied.

Having seen the need for management and organization of the applied research efforts, we shall examine a few basic concepts underlying this system.

Objectives

The only reason for the existence of a research and development laboratory is the attainment of certain well chosen and useful technical objectives. The setting up of these objectives is a prime function of the research management, since the later efforts call for the expenditure of lakhs of rupees and the employment of many specialists.

For good policy making, proper links with the technological, economic, social and political environments must be established. This will provide the basis for estimating the compatability of the products of research and development with the potential demands of the environments and of assessing that a development will not only be excellent technically but that it will be reduced to public practice with profitable results. The management of research and development must know not only the present state of environments but must be able to forecast future economic, social and geopolitical demands. The problems are difficult but important enough to warrant a full time attention of a staff group specializing in a study of environmental communications and operations analysis to assess and synthesize the relative potential values of different developments. The objectives chosen must be within the competence of the organization to deliver at the proper time products that meet the requirements imposed by the environment at that time.

Once these objectives are set, the function of the laboratory must be focused on achieving the results, in time at minimum possible cost with high standards and imagination, i.e. to develop the objectives to production worthy models. Hence during the course of research itself economic assessments to decide between alternative routes will be essential to achieve these objectives, which have time and cost factors.

In a well-balanced research programme, there must be groups of programmes representing different stages of development—the technology needed must be coming from the drafting boards and completed field trials; technology that is needed in the next five years must be well under way in the laboratory or pilot plant; the objective basic research that will solve the country's problems in the more distant future must be under active study in the laboratories and in the minds of creative scientists.

Communication

Through majority of our daily activities, through speech, writing and publishing we try to communicate. Communicating the correct thing at the right time with a minimum loss in communication is no simple art and today communication is a special field by itself.

Once the objectives have been set, they have to be understood by all levels of the organization, to see whether their work fits into the attainment of these objectives. In most research and development activities, timeliness and clarity of communication are extremely important. A network of communication channels to carry clear, certain and timely information must be established. Vertical channels are essential for spreading a sound knowledge of the objectives throughout the organization and for ensuring that new ideas generated at any level receive prompt attention at the top. Effective horizontal communications are the best assurances of avoiding the negative effects of duplication and enhancing a positive effect of exchanging knowledge and critical discussion. Cross-fertilization between the fields of science produces the highest level of perception of the problem within the group. Mutual understanding among individuals promotes better communication and vice versa.

The science of documentation from the wide literature and the information engineering to post the scientists with the latest developments, propagation of the research results and arousing the interest of others etc., are all part of the communication systems.

Time

The applied projects have to be time targeted since the goods are to be delivered at a time when they are required. Time is the commodity in shortest supply and is the basis on which all compete on equal terms. The prime function of research and development management is to devise and operate an organization that makes the most effective use of time. This requires the combination of thought and action that keeps the organization ahead in quality and quantity of its output. In addition to the successful planning, this also demands constant scrutiny to detect and eliminate time wasting activities.

The value of network analysis, using tools such as the Programme Evaluation Review Technique (PERT) in this field need not be overstressed. These techniques permit the events necessary to achieve a given end to be analysed and arranged in a logical order and result in the reduction of

time necessary to carry out complex operations and in the more effective use of materials.

Delegation

The growth of an organization does not necessarily call for expansion in size. Through enthusiasm, widespread competence and industry, a small organization can often do more than a large one. When people feel enthusiastic about their objectives and their works, their productivty goes up and often will excel that of a group of high calibre but bored investigators. Growth of the individuals and their output is the essential factor in the healthy growth of an organization. A policy of delegation and an atmosphere of enthusiasm promote this growth and the consequent output of the organization.

Detailed control from the top fails to take into account the great need of intelligent men to express themselves by the exercise of their individual judgement and in so doing act as free men. They in turn become cogs in a machine driven only by the centralized force of decision at the top. Wherever excessive attention is paid to details there is a tendency to drift into regions of low return.

The great need is enthusiasm at all levels and nobody who lacks enthusiasm can inculcate it in others. Not only must the staff feel a corporate pride in the achievements of the laboratory as a whole but each individual must feel that his or her part in the accomplishment is recognized. Delegation of responsibility to individuals inevitably results in their developing effective qualities of leadership in competence reinforced by confidence and decisiveness tempered by responsibility and these are very essential to tackle the numerous problems encountered in complex development. However, it should not be forgotten that without a proper coordination and communication mere delegation can lead to a chaos.

In the true sense research cannot be directed. However the proper leadership in a group can and should be the focal point around which day to day problems can be resolved. The researcher must be chosen for his ability to operate successfully within the group and the leader of the team must be an integrator and persuader rather than the boss.

Diversity of talents

The successful research and development organization needs the cooperation of many types of mind and skill to carry out the great variety of tasks that lead from an imaginative concept to a well engineered device, commodity or service. An important function of the management is the matching of assignments to the capabilities and mental attributes of the individuals together with the establishment of an atmosphere wherein excellence of any kind receives full recognition.

The various types can be (i) creative mind, which tries to inject something new into anything it does, (ii) cumulative and inductive mind ranging from literature experiment, collecting facts and putting them in order, (iii) cumulative and descriptive mind, remembering everything and describing it clearly for others, (iv) meticulous mind concerned with search for accuracy and precision, (v) routine industrious mind which follows relentlessly repetitive processes to establish a fact, and (vi) critical and analytical mind so needed for clarification of complex situation. For a steady growth of all branches of science and engineering all these mental

attributes have important roles to play. The meticulous worker who spends years in establishing the real facts in a complex situation or in perfecting a technique, or a routine industrious worker who explores an area thoroughly by a long series of measurements, provides means and materials for the inductive thinker and the creative artist, which they might not be able to get for themselves. The critical mind keeps thought and observation on the track, paying particular attention to the coherence of inputs and outputs.

Thus the methodology in the industrial creative process includes problem orientation, accumulation of knowledge, incubation, idea formation, critical evaluation and verification. Each of these steps can be understood and specific stimuli techniques are available which will bring about a high level of performance in each step. The secret of efficient use of manpower either on laboratory or a nation-wide scale lies in assigning to each mind a job suited to its attributes and carrying with it full recognition of contributions to a worthwhile objective. The placement of scientific talents should be approached more realistically on the basis of the mental attributes of scientists and engineers rather than on the basis of their professional training alone. If creative minds are set to work on routine problems or vice versa, even in the fields of their own training, frustration of men and general waste of time will result.

Efficiency and administration

In research organization, creative work of scientists is supported by the work of great many other people, some technical and some non-technical and that even among the scientists, there is a great deal of work that does not require so much creative effort as it requires creative planning and organization. If they are taken together, they will make up a large share of the total effort of the research organization. Truly creative work may account only for 10 per cent of the total expenditure of the research institution. The work of these auxiliary services can be examined closely and their working efficiency improved. This will include office type work, development programmes, pilot plant work, planning of these programmes themselves, engineering work, field work such as project follow up and other management activities.

The correction of situations like this not only cuts down research costs but also keeps a great many people from unnecessary activities. It is certainly not true that trying to get costs down necessarily results in less work, poor morale and frustration for creative people; just the opposite usually occurs and an efficient organization can eliminate a great deal of red tape, confusion and frustration and stimulate high morale and high productivity.

The main purpose of administrative practices is to facilitate the operation of the organization in such a way that the objectives are attained effectively and expeditiously. However, when these practices begin to absorb energies that should be devoted towards attaining the objectives of the organization, the time has come for drastic pruning and elimination.

Growing and changing attitude of management

The very nature of research and development itself is to bring change and how will this be possible if the research management itself is not willing to change at its own level? Management of research and development is an art, which is to be carried out in an atmosphere where criticism

is free. A particular structure or set of practices may serve excellently for the achievement of one technical objective and be quite unsuited to another. Many institutions suffer from the very fatigue of objectives, which reflects on the staff and its output. Unless the organization can change its technical practices and habits and is alert to the necessities of such changes, this negative factor will slow up its output and diminish the self-confidence and enthusiasm in individuals to embark on new programmes.

Other problems

There is a fundamental difference in the approach to commercial problems on the one hand and to scientific and technical problems on the other, which not all scientists in management can reconcile. The scientist patiently gathers together his data and makes his decision when his data are complete or at least sufficient to justify a logical conclusion ; but the scientist facing a commercial or administrative problem has to make his decision when it is required with the data available to him at that time Hence a scientist in such a situation has to make some conscious adaptation of his thinking on management. The most striking factor in risk management is the necessity to deal with the intangible in a tangible manner, for, from the unknown of tomorrow must be derived the decisions of today.

At times concentration and success in a narrow field has led to the contempt of the problems in other broader fields. Thus there are many pure scientists who regard applied work as needing only a lower standard of intelligence and fail to understand the importance of the combination of powers of intellect and judgement which is needed for applied scientific work. The task of working successfully in a heterogeneous team of men is much harder than the indulgence of intellectual skill on abstract theorems.

Applied versus basic research

All the foregoing statements have been made keeping applied research and development in view. This does not mean to curtail fundamental work. Fears are often expressed that applied research will crowd basic research out of the national laboratories and thus cause an eventual attrition of work directed towards understanding of the fundamental physical laws underlying all applications. This concept is entirely misleading. It is only in the purely intellectual sense that basic science always precedes and underlies applied science. Men flew aeroplanes before they did basic research in aerodynamics. Applied research often reveals the need for basic research in a given area and provides an incentive for performing it. A good performance of applied research will always stimulate a healthy amount of basic research.

The aim of the research management is to do everything possible to eliminate useless and wasteful technical effort and not to curtail fundamental research nor to abandon all duplicate approaches to important problems, since competition is often the spur to progress. But we ought to examine areas where extravagant duplications or the vain pursuit of decimal points exist, critically and unflinchingly.

In the field of basic research, the role of management is one of complete restraint and non-interference. The management can play a role in getting the expeditions started; but once the workers penetrate into the unknown, they are on their own and decision for action must be taken by

those close to the front line, in the light of the new and strange situations that arise. Generally pure basic research is best carried out in the environment of a university, for, it provides its members necessary freedom to pursue any line of enquiry at whatever pace they desire.

Research productivity

It is generally agreed that one of the most baffling problems in the management of research and development is the establishment of criteria for evaluating the productivity of a group or organization. Five yard sticks which can well define the job of a research organization have been chosen and the answers to these can give an idea just how effective it is.

(i) Does the reasearch organization know what technology is needed ? (30% weightage)

(ii) Is the research organization creating the need technology ? (20% weightage)

(iii) Is the research institution helping to get research results applied ? (20% weightage)

(iv) Is the institution achieving the results at the lowest possible cost ? (20% weightage)

(v) The general attitude and approach of the research management (10% weightage).

A greater weightage is given to the choice of the problems, since an error created here is bound to create further inefficiencies at later stages. The overall management is a very vital factor and this too gets a greater weightage since the fourth and fifth criteria account for this. The underlying principle of such a study is the acceptance that there is usually a better way of doing things than the present method and the acceptance of the necessity for change for progress. The research institution itself can conduct an analysis of the past performance using the above criteria to see the progress it has made over the years and to find in which direction it needs improvement.

Problems related to India

The basic conflict between making quick decisions and scientific research has been referred to. In addition, in India there is the problem of a general resistance to teamwork. The Indian thought and action, whether it be in the region of philosophy, music or searching for the inner self in the remote forests, in general has remained individualistic. This is quite opposed to the large scale harmonious approach of the West in religion, music or dance. With the Indian background, it is much easier to achieve far reaching results wherein the individual rather than the team is involved.

Specially in the field of research today, there is an intellectual snobbery and as a consequence there is lack of recognition of the broader fields. This is mainly due to the stress, value and respect attached to the individualistic narrow approach rather than to team approach and decision. To a majority at the helm of research, management, organization, communication, critical analysis and other related areas seem to be obvious matters requiring only the use of common sense. This results in either complete neglect of the group meant for communication and other organizational

activities or staffing this group with men of low calibre. After some analysis, however, one will be surprised to find how uncommon the obvious is. Taking the process of critical evaluation alone as an example, this is a field where the true test of leadership and successful team operation takes place. There is no better way to destroy creative tendencies than to register destructive criticism during this step. One has to know that enthusiasm is an emotion. Under its stimulus a good idea has self-expanding qualities and it should not be destroyed, for it may not return easily the next time.

There is also in India a false feeling of contentment, specially in fields where it is least wanted. Improvement is a continuing process and there is no reason why a good process or product could not be made better. On the contrary we often tend to satisfy ourselves with our achievements by attaching overwhelming national pride and prestige to the indigenous process or product irrespective of its inefficiencies and high cost of production or by quoting our growth in terms of expenditure and man-power though it may reflect only an inflation and not any expansion.

In underdeveloped countries like India, applied research and development mainly falls within the realm of the Government, since the value of such work is underrated by the industry, which is run by tradesmen of short range view rather than by businessmen of long range vision. Consequently, this poses certain problems inherent in any public sector.

The motivating factors with the general areas of industry and university, tend to differ. Normally as compared to academic research, industry tends to offer large compensation, greater opportunity for advancement, better facility, administrative opportunity and in many cases work which is more interesting because it is directed towards a practical goal. In contrast, the university tends to offer more freedom of research, a better academic achievement, more opportunity for professional prestige and status. Normally the industrial researcher would have spent some time in the university environment and hence may be subjected to an apparent conflict between the academic and industrial approach to research. The individual feels that industrial management borders on intellectual dishonesty and that his scientific efforts are exploited and that his ideas are grabbed too early by higher levels of supervision and are unjustly utilized. Management's framework of business on the other hand is one of opportunism where the awareness of timing is important.

These conflicts must be resolved and the many differences must be reconciled. For this, the motivating factors within the company fall under communication. The individual is oriented to the company's policies, the operating general rules—patent and competitive—security regulations and the need for certain publication restrictions. All these techniques tend to diminish personal frustrations and remove environmental blocks which are imposed on the researcher. Unfortunately when the industrial research comes under the public sector, the motivating factors can never be strong. As a consequence there is either frustration or even a direct applied or development problem will be taken through a round about way touching all possible basic fields, which may give an opportunity to yield some degree of publication. With this approach, the stress on time targetting will be diminished. The release of half-baked processes often is not due to lack of competence but to the absence of motivating factors and lack of communicative and collaborative work.

As the research and development is mainly carried out in the public sector, it is needless to say that to achieve the best results, there ought to be

a close collaboration between research and industry. Since independence, science and industry have moved independently and it is now necessary that they should go together. Industrialists would do well to invite scientists to visit them as often as possible with a view to discussing the difficulties of production. Scientists also would help themselves better by undertaking study tours of the industrial plants trying to understand the problems of manufacture. The industry must cooperate in trying out the indigenous know-how and the scientists too, without merely blaming the industry, should organize their research effort in a productive way.

It will be ideal to have small group in each research and development institution of some size as a planning group specializing in the study of environmental communications and operations analysis to assess and synthesize the relative potential values of different developments. This group also must deal with network analysis, workstudy, factors connected with research productivity and help the top to take decisions, and to direct the research in a productive way. It is very essential to staff this group by men with wide breadth of outlook, and knowledge of what is happening in the other side of the fence and of general business, and the skill in communication etc., which are essential to the general management executive. We should not be content by forming any small planning or management cell only in the centre, since the study of such a group will be too general to be of help to tackle the day to day problems of the individual laboratories.

Conclusion

The research and development activities intended for the economic uplift of the country cannot be separated from the environmental factors. Since the operation of applied research and development involves cost and time factors and calls for the cooperation of the intellectual and practical talents of men of varied fields, the need for organization sets in.

Without proper organization and time targetted team work, based on clearly defined objectives, supported by suitable communication systems, and aided by other management tools, the return for the investment in research and development will be poor. Of course, when we spend large sums of money and manpower, accidents are bound to happen and some good results will be forthcoming; but the output will not be in relation to the input. Unless we accept that there is always a better way of doing things than the present method and the acceptance of the necessity for change for progress, our growth is bound to suffer.

Planning and Promoting Industrial Research

A.C. RAY
Planning Commission
New Delhi

The big and powerful countries of the world are those that had industrialized and used modern techniques to develop their economy. In every field of economic and social development there are pressing problems which call for scientific study and investigation and the application of the results of research. In economically advanced countries scientific research, which is fairly expensive, is carried out both for the pursuit of knowledge and to meet the social objectives, such as, to improve health or to raise standard of living by increased production of consumer goods and at lower cost. India, being a developing country, cannot afford to incur similar amount of expenditure on scientific research as compared to those of developed countries. Since our financial resources for scientific and technological research are limited, it is essential that we should be very selective in undertaking the programmes of research and highest priority for research should be given in the beginning towards achieving specific production goals in more deficit sectors of the economy.

Since independence, due to the keen interest taken by the late Prime Minister Shri Jawaharlal Nehru in science and technology, the Central Government have spent more than Rs 500 crores for carrying out scientific and technological research covering almost all the fields of study. The estimated expenditure incurred by the industrial organizations on research during this period was unfortunately meagre and is not worth mentioning. If a tax-payer desires to know what economic benefits have been provided by spending this huge amount of money on scientific research, it may be difficult for anyone of us to give a satisfactory and convincing reply. A promise of a bright future, at a distant date, is not likely to satisfy him.

If there had been a lapse, that could be attributed, by and large, to our going off the track either in selecting a problem or spending money for a project, which had little or no direct bearing to the economic development. Whatever the cause may be, specially due to the emergency, it is high time that we should concentrate all our energies and available funds to research which can produce immediate economic return.

It is an accepted fact that for the proper development of research atmosphere, there should be a certain amount of flexibility in selecting research problems, yet too much of freedom may not be to the best interest of the country. This point requires careful rethinking.

Although fundamental or basic research cannot be completely dissociated from applied or industrial research, yet purely basic research without

any bias to industrial development is perhaps a luxury at this stage of development of the country. In institutions, which have been set up for initiation, promotion and coordination of technological research and where the per capita cost per scientist is very high, there cannot be sufficient justification of scientists devoting their energies in fields other than those for which the institutions have been set up. It is considered that in the interest of the immediate economic development of the country, these institutions should for the next few years concentrate their full attention on applied and operational research and apply their minds to basic or fundamental research when the country becomes more or less self-reliant.

Unfortunately, whatever technological research these institutions are carrying out today, the results mostly remaining unutilized for the industrial growth of the country. The non-utilization has been, by and large, due to the fact that either the results of research done in the laboratories have not been convincing to the industries, who are the potential users, or the industrialists are not aware of such results. For these perhaps the responsibility rests on the laboratories or their administrators. This non-utilization of results of research by industry has created a gap between the laboratory and the industry.

When applied or industrial research is undertaken in the laboratories, its main objective should be for the benefit of the industry. So, it is essential that before embarking on a research programme in a laboratory a careful survey of the need for it should be undertaken in close collaboration with the user industry. Since there has been in the past little or no coordination between the laboratories and industries, many of the experimentations that had been carried out in the laboratories were not directed to the requirement of the specific industries and have more or less become infructuous. Perhaps, the position would have been different if the research projects would have been undertaken after a thorough market survey of the commercial and economic possibility of the project.

In case the laboratories feel that they have some genuinely good results which have not been taken up by the industry, the best course to prove their bonafide will be to start the industrial production under their own control or under the auspices of a sister organization with which they have a close liaison. If they succeed, the industrialists will automatically gain confidence in the results of the research in the laboratory. Once the industries gain confidence, it will go a long way off for the future utilization of their results.

It is estimated that during the Fourth Plan the foreign exchange requirement will be to the tune of about Rs 4,000 crores, out of which about Rs 1,000 to 1,200 crores will be for the import of spare parts and components only. If the industrial research aims at import substitution and thereby saving of foreign exchange and the benefit passed on to the industries, who are now depending more on foreign know-how, then the industries will gain greater confidence in the utility of research organizations in the country.

As already explained earlier, in India, our research should be production-oriented, the schematic chain of activities linking industrial research with production being : Research—Development—Pilot Plants—Design and Engineering—Production—Reduction of cost and increase in production. Although this chain does not completely represent the complex and manifold relations between all these activities, nevertheless it does give out the stages of planning of research in industry in a general way.

In India the biggest organization dealing with the scientific and industrial research is the Council of Scientific & Industrial Research. A country, like India, which is at present heavily dependent on import, must try to keep in the forefront the technological advance, and it must, therefore, be a primary objective of this organization to ensure the most effective means of providing support and encouragement for the application of new scientific and technological knowledge indigenously worked out in the industry. From this point of view the utility of the CSIR should be judged.

In the field of promotion of industrial research and the stimulation of research by industry itself, there appears to be lack of adequate arrangements for coordinating the activities of the CSIR with those of the industry. The division of function and responsibility between the CSIR and the National Research Development Council for the purpose of the promotion of development contracts is also not clearly defined. In short, in the industrial field there is a clear need for greater coordination and concentration of effort and for instituting of some means of ensuring that research is utilized in support of those activities which are the most important for the economy as a whole.

As the matter stands now, whatever industrial research the laboratories are carrying out, they are going only up to the third stage of the chain as indicated earlier. It is necessary that the gap from the pilot plant stage to the production stage in industry should be bridged over.

The primary aim of planning of industrial research in industry should be to establish this link. Unless this link is established, it will be futile to spread the activities of the research laboratories by investing more money and trained manpower. To eliminate this gap, in many countries it is considered that industrial research should be the primary responsibility of the industry.

In developing countries, however, the industries are shy of investment on scientific research as the results of these cannot be foretold and so depend on the proved foreign know-how. They should be encouraged by the government for starting research activities in their respective fields by giving incentives. The incentives may be in the form of tax rebate on the money spent on research and development or subsidy for research expenditure.

By establishing several cooperative research associations, the industries have given a proof that they are now realizing the importance of scientific research in their fields of activity. Perhaps, at this stage, the government should give more encouragement to cooperative research associations in different fields instead of making new ventures in establishing new laboratories as they will yield results for the economic development of the country earlier.

The most effective agent in making industry research-minded is competition—competition not only for the sake of profit, but also for the improvement of technical qualities of the product. This element of competition in industry is unfortunately lacking in our country. A second alternative for making the industry research-oriented is to make the existing research laboratories to have close liaison with the industries for selling their results of research. This may be possible only if the results are of genuine type, otherwise any amount of persuasion or get-together with industry will have

no effect. A third alternative is to introduce several economic and institutional measures which may be briefly indicated as follows :

(i) Industrial license for setting up new units or expansion of old units should only be granted if there is provision for setting up adequate research facilities for improvement of techniques and quality of products.

(ii) Individual units interested in creating research facilities should be allowed to set aside a tax-free fund of a reasonable size out of their profits.

(iii) More cooperative research associations should be established.

(iv) The established research laboratories should circulate brochures describing facilities they have in their organizations and the assistance they can give to the industry and invite the industries to pose problems to them on a contract research basis with a time schedule.

Regarding programming of research either in the established laboratories or in the industrial laboratories, the research programmes should be generally classified into three categories: (i) short range programmes; (ii) medium range programmes; and (iii) long range programmes.

Short range programmes

Short range programmes should be those developmental programmes where results can be expected within a year of taking up the work. These programmes will generally include improvement of technical skills, adoptation of foreign techniques and know-how and making of simpler import substitutes.

Medium range programmes

These should be connected with major products and processes, development of new processes and products and substitutes of raw materials, for which a result can be expected from one to three years.

Long range programmes

These comprise advanced technology or major break-through in the process or product. These programmes, if taken up, are likely to continue for a number of years. Besides these programmes, the other research programmes, which also fall under long range category, are those which are of fundamental and basic type.

While taking up a research programme, normally the highest priority should be given to short range programmes, as it will yield an economic benefit in the shortest possible time. In the *inter se* priority, the medium range programmes would come next and the long range programmes after that, but the long range programmes can also have a higher priority, provided they are expected to help long range economic development programme of the country, which also cannot be lost sight of.

As we have entered the era of development only recently, any ambitious long range programme either in the established laboratories or in the industries, may lead to locking up of capital and resources and frustration, which may not be desirable.

In conclusion it may be said that if the scientists and their administrators and the industries sincerely desire to become self-reliant, there is no reason why they should fail as talents are not lacking in the country.

Is Indian Industry Shy to Adopt Indian Processes ?

G. S. CHOWDHURY
Regional Research Laboratory
Bhubaneshwar

Before commenting on this vital question, it is necessary to analyse the basic factors involved in the establishment of an industry, utilizing a process or know-how developed in our country, particularly in the national laboratories, or for that matter, nay industry in general in India under the existing economic environment. The first question one is apt to ask often in this connection may be briefly stated as follows.

The industrialist or the entrepreneur has to face several problems to establish a new industry and develop it to a stage where it can provide reasonable return on the investment. In the present day banking practice, most of the banks and well-established industries are offering a guaranteed dividend by way of interest or otherwise at a rate of 8–10 per cent. A new industry or an existing industry has to provide for the following items before a reasonable dividend could be expected : Corporate tax, Income tax, Welfare expenses, Provident fund, Bonus, Interest on borrowed capital, Royalty on processes, Excise duty, Advertising expenses, Sales tax, Municipal tax, Factory registration taxes and Transport.

These are in addition to the cost of raw materials, labour and other overhead or managerial expenses.

The major problems of a new industry are finance, foreign exchange, industrial licenses, import licenses, raw materials, market survey, sales organization, etc. In the case of imported raw materials, there is a continuous anxiety regarding the import policy reviewed periodically by the Government, and also the uncertain price structure abroad for such raw materials, on the basis of which production costs and selling price of the finished goods will have to be continually adjusted. On account of this variation, there can be considerable fluctuation in the market and the sales. The monetary policy of the various banking corporations also plays a major role in the marketing and sales organization of an industry. Naturally, a new enthusiast will feel diffident to face all these problems if the returns on the invested capital after taking substantial risks in the production are only meagre and may not, in several cases, compensate even for nominal interest which he could have earned if only the entire capital is financed or invested otherwise in fixed securities. One would therefore ask the question: What is the incentive for one to overlook the various problems enumerated above? The motive force for any action will naturally depend upon the expected profit or returns on the investment. This obviously therefore should be quite attractive.

The processes developed by the various national laboratories intended for the private sector should therefore aim at a reasonable return on the

invested capital and not merely provide 6–8 per cent return in order that an industrialist may be attracted and persuaded to take up a known or newly developed process. If some of the processes presently being pursued by the various national laboratories cannot come up to these expectations and also cannot be justified by way of contribution to the national wealth or earning of foreign exchange, etc. it is worthwhile taking a serious look into these projects and assess them on the above basis.

While it is not the objective of this discussion to highlight the difficulties of an industrialist in the establishment of an industry, one cannot but overlook the importance and the psychological influence the above economic factors are likely to play. Up to this stage, the question of equipment, engineering skills, instrumentation and availability of skilled technical and scientific personnel to man the projects has not been taken into account. Obviously, the above will add to the complexity of the problem.

It is therefore necessary for us to discuss in greater detail how best the various problems enumerated above could be tackled in order to attract a new financier or an existing industrialist to take up new processes or developmental projects available with the CSIR. Since the major factor influencing the Indian industrialist today is the problem of finance and foreign exchange, and since most foreign collaborators are providing know-how in addition to participation in the equity capital, the common man is attracted to invest in such enterprises thereby facilitating financing of the entire project. A financier will naturally welcome such a prospect. To counteract this successfully, the following proposals may perhaps be considered :

(1) The Government of India should guarantee the minimum required foreign exchange for import of equipment, instrumentation, raw materials, etc. based on a process leased by the CSIR to industry.

(2) To attract the common man to take part in the capital subscription, the public sector institutions such as the LIC, ICCCI, the various state finance corporations, etc. may be encouraged to subscribe to a part of the equity capital and also to underwrite a part of the equity issue. The procedure will naturally infuse confidence on the subscribing public, and will contribute to success of the project. This procedure may be necessary for a limited period till such time the public gain confidence in new ventures based on processes released by the CSIR to industry. With such facilities available for capital contribution, the new financier will also come forward and will be prepared to take chances on the processes developed indigenously.

(3) The CSIR should on its part give an undertaking that based on certain cost of raw materials and the process know-how, the ultimate cost of the product will be well within certain permissible limits, and if there is any variation in the above cost, thereby affecting the marketability of the product, the CSIR may compensate for such failures in a suitable manner agreed to mutually.

(4) A separate fund to cover such risks may be constituted and kept under the control of a high-power authority of the CSIR.

In order to safeguard the interest of the CSIR naturally more intensive studies will have to be undertaken and a rigid assessment of the various processes should be undertaken on the above basis.

Since the Government of India and the CSIR are directly guaranteeing a new industry, the royalties and know-how charges could be levied at a fairly higher rate, in a similar manner as the Indian industrialist would have paid to a foreign participant. The amount so recovered could form the basis for such insurance against losses or failure of guarantees by the CSIR. Since this procedure involves certain risks to be taken by the CSIR and the Government of India, the project evaluation and release of processes to industry will necessarily be more rigid and a thorough investigation will be made by the various institutions.

The very acceptance by the CSIR and the Government of India of the procedural set-up suggested above will create confidence among the Indian industrialists who will naturally come forward to take up the processes developed by the Indian laboratories. The public financial institutions taking part in the promotion of a company are also taking considerable risks along with the CSIR, and in the case of all successful projects, a suitable share of the royalties may also be paid to the financing institutions to encourage them to come forward and shoulder the risks along with the CSIR. This will function like a tripartite insurance against such risks which ought to be negligible if the processes leased to industry are thoroughly scrutinized. In order to keep the know-how of a released process at a fairly advanced state of development and to ensure continuous utilization of the know-how, the CSIR has to pursue the process on the basis of the royalties received. A portion of such amounts may be allocated for continuous, concentrated and intensified research on such released processes, instead of becoming complacent about them. This will ensure continuous advanced development of technology and know-how, and will thus contribute to the ultimate growth of Indian industry on a competitive scale in the international market as well as ensure a higher stage of technology for future development.

The Government of India should further delegate the authority or evolve simplified procedures in the sanction of foreign exchange for import of essential equipment, instruments, and raw materials for any industry based on a process released by the CSIR. The ultimate authority for such recommendations should be the CSIR, and all other formalities should play a secondary role. This simplified procedure will further enthuse the new industrialists to come forward with confidence to negotiate with the CSIR for its processes. The industrialist will also have a guarantee of raw materials absolutely essentials ; he will also have the assurance that in case the essential requirements are not met due to financial or foreign exchange regulations, the CSIR will bear the responsibility of providing alternative resources for overcoming such handicaps. The CSIR on its part will naturally be more alert and work out newer methods and processes to progressively reduce the foreign exchange factor in its processes. A continuous research will therefore be necessary on this basis.

Under the present day conditions in our country, one has to face a shortage of institutions that could make available the engineering skills for the design, fabrication, and operation of new plants and projects based on indigenous know-how and processes. It is, therefore, essential that in the overall interest of the country, the CSIR and the Government of India should make additional efforts to organize and develop the engineering skills and consultancy services for various industries. These services will prove immensely successful and in course of time able to earn dividends for the Government. There will be a considerable saving of foreign exchange

also. The active association of the various scientists and technologists in the developmental work relating to these projects will help in continuous assessment and development and also in the solution of day to day problems associated with any industry. The regional institutes established for this purpose in the several states should be entrusted with such responsibilities to assist the local industries in their general production problems which cannot be ordinarily tackled by the staff of the industrial concerns themselves. This procedure will improve the quality of work in the various national laboratories and also help in the proper appreciation of the industrial problems, the development of better processes keeping in view the industrial resources, etc. It will also be necessary in the initial stages to have periodical exchanges of personnel between industries and research institutes and scientists may be encouraged to take active part in specific and selected industries in the field of their specialization. The scientists will thus be armed effectively to tackle the problems as and when they arise, with greater confidence and understanding.

The next phase of the problem concerns the evaluation of process cost, and the ultimate selling price of a commodity based on the CSIR process. Since the entire success of a process is governed by the ultimate economic selling price, greater attention should be paid to the systematic evaluation of the product cost. All the processes now being pursued with a view to licensing them to industry should be subjected to rigid cost accounting procedures so that the ultimate cost could be kept well within reasonable limits.

In this connection, it is absolutely necessary, under the present legislation, to take into account the various additional expenditure by way of bonus, provident fund and other welfare benefits to the workers engaged in these operations. As these costs, including corporate and other taxes, excise duty, etc. may influence the ultimate cost of a product, one cannot afford to neglect the above factors in arriving at the ultimate price of a product. Since the distribution costs are also controlled to a large extent by transportation costs, the ultimate consumer price has to be borne in mind while assessing the acceptability of the product by consumers, which will indirectly reflect increased or decreased sales, i.e. ultimate profit or loss in the operation of an industry. At the present moment, perhaps most of the above factors are not being taken into consideration, but these are very relevant, and should be considered in greater detail in all the future cost estimates for processes available for release to industry. As has been emphasized earlier, the industrialists expect to have a reasonable margin on the invested capital by way of dividend over the normal interest or other investment returns in relation to banking operations, and also a certain factor of safety for marginal adjustment in the cost of the product due to unforeseen variations in increased costs of energy, coal, and other unexpected fluctuations. Even the import duties on the raw materials, replacements, etc. may sometimes upset the entire economic balance of a process. It would therefore be necessary to provide an additional safety factor to compensate for the above factors.

If the indigenous processes are thoroughly scrutinized in the abovesaid manner, the industrialists in India would no doubt come forward and take active interest in establishing new enterprises based on indigenous know-how.

The next phase of the problem is to create interest among the Indian industrialists and financiers to participate in the formulation of the various

research projects at the several institutes of the CSIR, as these projects are necessarily to be related to the solution of problems of the industries. A part of the work of the institutes could be advanced fundamental research without which applied research cannot progress effectively. The major emphasis will therefore be on applied research in relation to industrial problems identified after a critical appraisal by industrialists, technologists and scientists with intimate personal knowledge of the problems facing the industries today.

Normally, an industrialist is shy or is afraid to discuss the nature of his problems with the fear that a disclosure of his difficulties may adversely affect his sales. This will naturally mean that the CSIR institutes should have personal approach to the local industries and infuse confidence in them and assure them that their problems will be kept strictly confidential and will not be divulged to others. In certain cases, it may even be necessary to undertake developmental work on the basis of suggestions made by a local industrialist exclusively for his own use. Once he is satisfied that he can safely trust the institute, he will come forward with all his problems progressively. Depending upon the personal approach, it may be impossible to induce the industrialists to bear a part of the cost involved in such developmental work as the industrialist genuinely realizes that advanced scientific and technical know-how will improve the quality of his product and also help in the reduction of the ultimate cost of his product. A quality control is thereby established, and the industrialist can look forward to sell his commodities in competitive markets with greater confidence and reliance.

A close relationship between a research institute and the local industries is therefore obligatory. Thereby one can reasonably expect an increase in the number of research projects sponsored by industries operating at the various institutions.

In furtherence of the above objectives, it will be necessary to strengthen the various research institutions with good publicity, liaison and information divisions to continuously cultivate intimate and personal relationship with the industries. The recent decision of the Governing Body permitting the Directors of national laboratories to accept directorships in some of the industries will go a long way to further personal relationship between industry and the national laboratories. This step may therefore be considered as a very realistic approach to the above problem.

In order to cultivate a sustained interest among the Indian industries in the activities of a national laboratory located in a particular region, it is advisable that such institutions periodically carry out an intensive publicity campaign and also supplement the same with documentation helpful to the local industries. Such documentation may preferably contain abstracts of literature on recent developments in various types of industries, advanced technical know-hows and newer developments of equipment, instruments, etc. all over the world. Most of the industrialists during personal discussion have expressed a keen interest in such publications and have even agreed to contribute a share of the expenses in such projects. This aspect of documentation and publicity has to be given more prominence in the future activities of the CSIR institutes.

Periodical seminars, technical lectures, symposia, etc. may also be organized at different centres in the country in order to create opportunities for exchange of ideas which will benefit mutually the industrial

technologists and scientists and the research workers of the national laboratories. In this connection, it may also be necessary for the scientists to go round the country and study particular industries in greater detail and discuss on the spot the local problems relating to the industry in particular, and other problems in general.

Thus by a continuous maintenance of mutual contact between industry and the research institutions, it will be possible to create active interest in the industrial sector on the activities of the CSIR, the national problems, etc.

In the light of the above discussions, it is evident that the confidence of the industrialists can be won over, provided the Government of India firmly supports the policies of the CSIR and implements the suggestions enumerated above to carry out smoothly the various projects. This is paticularly important in relation to the financial aspect. It is necessary that the Government of India declare its unequivocal support and lay down the policies whereby the CSIR, backed by a monetary grant, the LIC, and the Industrial Finance Corporation, and other state financial institutions jointly support the industries by undertaking to provide equity participation in capital and also underwrite its equity subscription to infuse confidence in the subscribing public. The support rendered by the Government by authorizing the CSIR to recommend foreign exchange allocations for import of raw materials, equipment and instruments, and by simplifying the procedures will reflect progressively in better utilization of the indigenous processes and technical know-how developed towards better utilization of the natural resources of the country.

The Government can also assist the CSIR by making it obligatory that all public sector projects should utilize the indigenous know-how wherever it is available, and making it a rule that a representative of the CSIR should invariably be associated in every developmental project in their technical sub-committees. In this manner, when the public sector itself extends its support to the CSIR, the Indian industrialist will only be too glad to fall in line, although cautiously.

I would, therefore, like the Conference to consider the basic factors involved in this programme and make suitable recommendations to the Government of India.

Applied Research

V. G. RAJADHYAKSHA
Hindustan Lever Limited
Bombay

Defining objectives

A principal difficulty in applied research is to locate and define the problem fully in terms of the quality of result required and also quantitatively the value of such results. The laboratories and scientists working on a problem should have precise information on what is expected in the end, how their results will be utilized and what specific benefits will accrue out of their projected work. A systematic approach to this is suggested and the following steps may be considered.

(i) The laboratories and scientists should have close consultations with the ultimate users of the research work. In some instances such consultations may be held with trade or industry organizations such as Chemical Manufacturers' Association, Vanaspati Manufacturers' Association and Indian Soap and Toiletries Manufacturers' Association.

(ii) The Indian Standards Institution Committees are composed of representatives of trade, industry, government and research and perhaps these committees could be induced to define problems in a clear manner. The members of the ISI Committees have detailed knowledge of their subjects and they are likely to present a consolidated and realistic view of their special industries.

(iii) Much broad guidance in the definition of problems is derived from the Executive Councils of National Laboratories. In laboratories which are connected with a specific industry, e.g. glass, leather, fuel, metals, there is a definite association with the industry through the Council. In other laboratories, it would be useful to define more precisely their area of work and then reconstitute the Councils to suit this area.

Forward planning

In a planned economy, it is possible to indicate where growth will take place and what the needs of specific industries broadly speaking are. Once these plans are agreed upon in new sectors, it is necessary to decide if technical know-how is to be obtained from outside the country or developed within the country. There is no national policy on this important question and both the alternatives are followed with varying speeds simultaneously and the initiative for following these courses of action is left largely to unconnected individuals, scientists and laboratories. At the rather late stage of consideration of proposals of manufacture, the relative advantages of outside and local know-how are evaluated and there is wastage of effort.

It may be desirable, therefore, even at the early date of formulation of national planning, to choose a certain number of operations for which knowledge will be developed within the country and then arrange for a national laboratory or industrial organization to develop the know-how within a specified date. The research and development effort required should be evaluated and sufficient staff and facilities should be provided for meeting targets on schedule. The information produced out of research should include such items as design or choice of equipment, process details for large scale operations, power/fuel requirements, disposal of by-products and effluents etc. The cost factor should not be forgotten and realistic costs of production should be provided.

In planning of this type, it will be possible to make an estimate of all raw materials, equipment and spares that need to be normally imported and the value of such imports. From this estimate and the availability of research facilities, a clear view should be taken, right at the start, which of these materials and equipment could be produced locally within the target date and which should be preferably imported at least for the present. A specific laboratory or organization should be made responsibte for developing the substitutes within the prescribed time.

Duplication

There is a definite need to conserve the total scientific resources and avoid unnecessary duplication of research. Several problems are being pursued simultaneously in universities, national laboratories, state and central government research stations, agricultural and medical research councils, defence organization, atomic energy department and nationalized and private industries. A certain amount of duplication is unavoidable and perhaps useful, but on a large scale it is very wasteful. Although this is agreed, there is no national coordinating agency with sufficient powers to stop wastage of efforts. Much as any individual or organization may feel they are more suited to tackle some problems, they must yield gracefully to counselling from a coordinated agency and reallocate their efforts in a fresh direction.

Research laboratories and organizations have, to some extent, evolved to their present size and state as a result of the personalities of scientists involved. Many investigations and branches of science have been pursued purely out of the initiative of the scientist concerned. There is a need to evaluate the role of each laboratory in the present context and see if some regrouping of laboratories and changes in personnel would not serve as an impetus to rethinking. An exchange of scientists between laboratories may again be desirable to bring home the need for avoiding wastage and duplication and for inculcating a healthy appreciation of work of one laboratory by others.

Progress of research

Once objectives, priorities, target dates and responsibilities of individual laboratories/organizations are defined, a careful follow-up is necessary to ensure satisfactory progress. The Governing Councils of laboratories/organizations, while they are suited to define the broad objectives, cannot themselves watch over details. The following measures are suggested for ensuring fruitful research :

(i) The scientists who are actually conducting the research should have close association with the actual users of results. Small panels of people

drawn from industry, such as technical directors, production managers and research and development scientists should meet fairly frequently the scientists working on the problem. Scientists should be encouraged to visit production units. Liberal financial arrangements should be made for these exchange visits. The suggested close association will help to define the details of the problem and avoid wasteful effort. The scientist will also have a sense of reality and urgency and will be able to appreciate the relevance of their successes and derive satisfaction.

(ii) Panels of this type should be charged with the responsibility of submitting reports on the progress of work. A balanced picture of the progress will emerge from such reporting. These panels should also state reasons for any lack of progress and propose what steps are necessary to ensure satisfactory rate of progress and for meeting schedules. These recommendations should be given effect to as soon as possible.

(iii) Research personnel should work in industrial organizations when research processes are adopted for manufacture, so that a genuine appreciation of problems is obtained. Similarly an attempt should be made to employ in research organizations, some personnel with a certain amount of experience of industry in India.

Evaluation of research

Applied research can be regarded as successful only when it is finally utilized in manufacturing operations. Effective research should be capable of surviving competition and should clearly demonstrate the advantages that will accrue from utilization of research. The research worker himself is necessarily a partisan judge of his efforts. For a legitimate evaluation of research, the following steps are suggested :

(i) Evaluation of applied research results should be carried out by eventual users of results and their views should receive attention and publicity. The different sections of reports of progress of laboratories should show how the results have been assessed and what opinions have been expressed by potential users of products and processes. The names of assessors should be included in these reports.

(ii) The end quality of products is of vital importance and relevant standards such as Indian Standards should be applied.

(iii) The economic aspects of new products and progresses should receive careful scrutiny. Better utilization of well-trained and imaginative cost accountants will be most useful. The cost of research should not be much too excessive in relation to any gains made.

(iv) The gulf between a laboratory result and manufacture should be bridged by careful pilot plant work and project feasibility studies. Such project studies should be published after due patent protection etc. and these publications should indicate clearly the economic advantages of the new development, duly supported by evaluation from users and potential users.

(v) The Head of the research organization/laboratory should have the overall responsibility of ensuring the completion of projects on schedule and he must in turn have sufficient powers to allocate facilities and increase efforts. The evaluation of research results and priorities must go hand in hand with the allocation of financial resources and the evaluating authorities must participate in deciding on changes in facilities and extent of effort.

(vi) Before new projects are started, a careful assessment of what is already known is necessary. Where small adaptations of known processes and designs would suffice, a large investigation to evolve completely new ones may not be warranted. An outside expert may often be the best judge of the situation and could advise as to whether such projects are worthwhile.

(vii) The Governing Councils must take keen interest in the work of laboratories and should consist of people who are anxious and willing to take considerable interest. They should meet at least three or four times a year. Wherever necessary they should be free to invite experts to advise them and to consult potential users for evaluation. The Councils should be statutory bodies and their composition should remain constant for sufficiently long periods (about five years) so that they could maintain continuity and have time to judge the outcome of their guidance. The Councils should have adequate powers to institute, terminate and modify projects. Ultimately the Councils should have the responsibility of proving that with their guidance and direction, effective research of direct value to the country is carried out in their laboratory.

Import substitution

Due to shortages in foreign exchange, industries are already conscious of the need to develop and use local substitutes. Many industries find imports to be highly expensive as the necessary foreign exchange is obtained through credits obtained by exports, which are made at a loss. Such industries are thus able to evaluate precisely the cost of imports and are willing to find and use locally made materials. They are also in a position to place a value on the research needed to find local substitutes.

In any research and development work on evolving and producing import substitutes, an incentive should be provided by assigning a definite quantitative value for such substitutions. Routine substitution work is not always intellectually stimulating and many research organizations do not therefore wish to put forth much effort in this work. However, if a quantitative basis could be provided, the value of their work becomes apparent. Again substitution need not be a direct replacement. Imaginative work may lead to unusual substitutes and even novel new products. If information on the nature of use to which the imported product is put is given, then the opportunity for research widens and the chances of success become greater. Here again, the evaluation of the quality and cost of substitution must be left to the user and he should not be suddenly faced with a ban on import, merely on the basis of research claims. A mutual confidence cannot be built up in this way and the type of information the researcher needs in the future for carrying out effective work, will then be no longer easily available.

There are essential goods and imported strategic materials for which local substitutes must be found quickly. Here the cost of not having local substitutes can be very high and again, some quantitative assignment of value to such imports will stimulate research.

The full value of research on evolving local substitutes cannot be realized until manufacture of substitutes starts. There are sometimes delays in commencing manufacture and streamlining of procedure for various permissions will be very valuable in making the country more and more self-sufficient.

Imported Technology and National Development

J. C. KAPUR
Airconditioning Corporation Ltd
Calcutta

In terms of broad economic objectives, we have over the years endeavoured to strike an acceptable balance between various aspects of national development. Nobody today can challenge the facts of our growth, some may challenge the rate of growth, but all the indexes cannot hide the fact that our techniques have tended to create a state of serious imbalance in the various sectors of our national effort ; be it industrial development, agriculture, education or social services. Wherever we have endeavoured to accelerate the rate of growth, these imbalances in the situation have come into glaring focus. The intense activities and prosperity of a section of our community have created an illusion of great progress. In reality it is like the whirlwind appearing to drag the earth.

An overall state of balance cannot be restored so long as we do not bring each constituent sector of our national effort in line with the needs and aspirations of a large mass of people in this country, and assure their active participation by taking into consideration their genius, limitations and adaptability to the exigencies of a modern state.

Our first and the foremost problem has been, still is, and for generations to come will continue to be, the creation of employment opportunities and work for the people and raise the entire community from centuries of stagnation and a morass of poverty. To examine the contribution of research and industry, its present orientation in terms of our immediate and long term objectives, is indeed the purpose of this presentation.

Under normal circumstances scientific research generally precedes economic development. The scientific worker continues to build new concepts on the foundations of the old in a slow and steady process. As men always remained ahead of the techniques, their adaption did not pose any problems because it became a part of the life and culture of the people. In India, on the threshold of development, it was the problem of adaption of techniques to men at all levels, in all spheres. The purpose of the organization of national laboratories in the post-independence period was, to set the pace for country's technological organization in terms of the genius and the needs of the people through rational systematization of the available technology. The laboratories could have contributed considerably in the multipurpose utilization of instruments and techniques and their simplification and acceptability. The available talents and resources were, however, inadequate to meet the great challenge, which the vastness and the variety of India's needs posed.

The development plans called for massive steel plants, fertilizer factories and hundreds of other industries using sophisticated technology. As the country pushed forward towards broadening its industrial dimensions, the lack of experience and general failure of the research organizations to make their contribution, brought about an almost complete import orientation of these industries. It would be fair to say, that national scientific research has made a very limited contribution to the process of technological development. There may be a few isolated instances of valuable service, but no heart warning trends.

These developments have in turn established a system of technological communications with other countries. This has also affected the thinking of policy makers, administrators, technologists and workers.

The import orientation of our development plans is even conditioning our objectives and overemphasizing spectacular achievements in a few chosen fields rather than a broad-based slow march into a modern state.

Therefore, what really started as a catalyst to break centuries of inaction and to serve certain urgent needs, has in the process of years, become a state of mind. Today, whether it is the setting up of major basic industries or large consumer goods plants, highly sophisticated or small scale industries, the emphasis all along is on imported technology. The shear weight of benefits in easy success, large financial returns and prestige has brought about this condition. The underlying motivation is the same, whether we import food or technology.

It is by no means the intention to belittle the massive contribution made by imported technology from friendly countries; in broadening India's industrial base and bringing about self-sufficiency or near self-sufficiency in many spheres of national endeavour. Furthermore, imported technology has set a high tone and standard in our leap forward across centuries of inaction. If this process could have continued for a few more decades in peace, we in this generation, would perhaps have been spared the unpleasant necessity of having to face the facts of life ; that the ultimate success of the development plans of a country of the size of India could only succeed by the unprecedented effort, will and sacrifice of her people.

It is therefore important for us to assess the immediate contribution, and the long term problems created by an overemphasis on imported technology vis-a-vis our drive for scientific and technological self-sufficiency in India. Some important contributing factors which are delaying the development of indigenous talents and effort could be summarized as follows.

In the public sector enterprises, the basic decision with regard to the major developments in the country rests with the administrative cadre rather than the technologists. As a result, while we have developed a large group of administrators, relatively speaking a few high level technologists have emerged on the national scene. This has contributed towards making the imported technology and its implementation through experts from abroad, virtually indispensable. If it is desired to correct this position and the technologists have to be called upon to make a major contribution, some significant changes in decision making machinery would be called for. Without such changes, indigenous developmental efforts for years to come would be confined mainly to paper work.

In a large section of the new private sector industries in India, foreign collaborations have helped in bringing about the highest returns in the shortest possible time, with the least amount of risk and minimum reliance on Indian technicians. An emphasis on indigenous technology by its natural consequences will necessitate the power of decision being passed on to the technicians.

Both in the private and public sector industries organized during the recent decade, the emphasis has all along been on advanced technology. There are relatively few persons in the country who could effectively deal with many aspects of such technology, and as a result, the entrepreneurs have been obliged to rely on imported know-how. The lack of technical orientation in management and in many instances, the inability of the decision makers to assess the significant points of attack in order to realize indigenous self-sufficiency, have been responsible for the unusual delays in realizing this objective. The supervisory staff, skilled, and semi-skilled labour in many of these industries often get oriented to certain techniques of production wherein individual initiative does not play a very important part.

It is well known that some of the more sophisticated equipment required in the implementation of projects using advanced technology, are not available indigenously. It becomes therefore necessary to seek foreign partners on a financial participation basis to obtain such equipment. Furthermore, even in the negotiation of Indian finance, the financial institutions in the country have been known to give special consideration to the projects with foreign technical assistance. In most instances, technology also involves the use of imported raw materials and components. In quite a few cases, where the number of units produced are relatively small, and a few high technology, high priced components are required to be imported ; indigenous self-sufficiency becomes a different task, or atleast highly uneconomical for the manufactures. One of the more serious aspects in the development of industries with imported technology is that arrangements have been made to produce many models, sizes and designs of equipment with many different countries, for the manufacture of the same product. This approach is very significant in a buyers' market, as it gives the consumer a fair deal. But in an economy such as ours, with a built-in-sellers market in a very broad range of products, the benefits transferred to the consumers are relatively speaking very few; while on the other hand, this approach has made the task of product, material and component standardization very difficult indeed. This has seriously affected our drive towards indigenous self-sufficiency and maximum utilization of technical and other resources. Varying levels of indigenous content, in same type of production; and approach of different policy for each manufacturer, has not helped matters.

No real effort has been made to assess the indigenous capabilities in the manufacture of equipment for large process industries. The savings in foreign exchange from one such plant would be adequate to meet the raw material import needs of many essential import oriented industries. To achieve this objective it would first be necessary to shake off over dependence in matters of plant design. The employment of a few thousand extra workers in industries catering only to our internal needs, is not after all, too serious a matter.

In the United States and many other countries, bright scientists and technologists with worthwhile ideas and inventions are in a position to

put them to use and thus promote their own and their country's interest; while here in India, the overwhelming odds of imported technology, and large capital have not permitted this class to emerge to any reasonable extent. A factor which will continue to be a drag for quite sometime to come, is the fear of some of the entrepreneurs to set up new enterprises in competition with the existing enterprises which are supported by large finance and imported technology. In cases, where there is still scope for further development, the fear of future inroads of imported technology is acting as a disincentive.

By the very nature of the collaboration agreements, the continued research on new products, material and techniques is the responsibility of the foreign collaborators. As such, this information is made available to the industries in India as and when it is considered necessary by the collaborators to do so. This, as will be appreciated, for obvious reasons, maintains the Indian industry at a lower stage of technological development all along its existence. These industries no doubt serve to increase the national productivity to meet the internal demands but could not possibly outstrip the parent companies.

In recent years, one of the strongest arguments that we have used in favour of advanced technology is the need for export orientation of industries, so as to enable these industries to compete with the products of other highly developed countries.

Though there are a number of isolated instances where this approach has made some contribution to export, yet, by and large this approach has still to be justified, and has in many instances worked to the detriment of our export drive. In India, as in Japan and elsewhere, the backbone of the export drive is formed by the industries which are not more committed to imported technology. Japan's leap forward in various fields such as cameras, electronic equipment etc. should be an eye-opener.

Imported technology involves many direct, indirect and built-in costs including the initial payment, planning costs, royalties, cost of negotiations (such as travel, personnel costs), profits in the supply of components and raw materials and additional profits due to lack of competition. These factors which vary from one industry to another and one country to another, need to be assessed. While it is necessary to pay this price in realizing certain broad objectives, yet how far these objectives fit in to the overall pattern of national development will have to be carefully ascertained.

In order to regulate this situation, the Government has from time to time taken certain steps including the reduction in import quotasenhancement of duties and restrictions on collaborations. While in many instances, these policies have helped considerable rigidity and applications of the same policy to different situations they have not contributed towards broadening the productivity base or indigenous self-sufficiency.

As will be observed while fulfilling many urgent needs, an overemphasis on imported technology and its acceptance without adequate assessment in terms of long term national needs, have placed the entire process of self-sufficiency—productwise, equipmentwise, raw-materialwise, technologywise, personnelwise out of perspective.

If it is intended to restore the indigenous talents and research to the position of leadership, so as to accelerate the processes of self-sufficiency,

we would first have to define our terms. Self-sufficiency can be qualitative or quantitative. Applied to defence, it may not just be the question of the number of guns that we can produce, but the nature of duty that we expect from these arms. We may be quite self-reliant with regard to the first objective but not the second. If the drive for food production conjures up in our mind large earth moving equipments and tractors, we may not be self-suffcient for years to come, but if we are talking in terms of simple agricultural implements and know-how to supplement and improve the farmers' efforts, we can be self-sufficient within a relatively shorter period of time. Self-sufficiency, in a very large sector of our national effort is not limited by consideration of imports or foreign exchange. 'Are we self-reliant in these fields?' is a question that we could profitably ask ourselves.

Broadly speaking, our immediate problem concerns the maintenance of production at the maximum with minimum expenditure of foreign exchange. The substitution of indigenous for imported raw materials or scarce materials in short supply with more readily available materials, should with experienced analysis, be relatively speaking, an attainable objective. Special care should, however, be taken in the case of such industries where non-availability of some of the fractional requirements of raw material and components, may mean large drops in production.

The indigenous manufacture of essential components hitherto imported, would comparatively speaking be a very intricate problem. As referred to earlier, in many instances for the manufacture of one product, we have technical collaboration with half a dozen companies in different parts of the world. While the end-product serves the same purpose, its size, design and other characteristics are quite different and it will not be possible to make important changes except with the complete cooperation of all the units and their foreign collaborators. One way of realizing this objective would be, that organizations representing different industries or relevant committees of Indian Standards Institution where possible, should be called upon to invite important manufacturers to get together and investigate in detail the requirements of raw materials and component parts within their sphere of activities. Such a step would give greater confidence to manufacturers to effect industrywise substitution without competitive disadvantages.

Another aspect of the question, which would need to be investigated is, that often five industries producing the same end-product have different percentages of imported content in the total value of their production. The rationalization of this position would require major adjustments by new manufacturers, and may in many instances work to their serious detriment.

In many instances, while the component parts of an automobile, such as a dynamo or a refrigerator and air-conditioner, such as a compressor or thermostat are being produced in the country yet the raw materials or special parts of these accessories are still being imported. It is only by studying the problems of various industries in depth, that we can place the problems in their proper perspective, and take effective steps.

While it is not the intention to question the more than worthwhile objective of indigenous self-sufficiency, yet it is required to be determined whether the necessary capabilities to tackle problems of materials and technology in a very broad spectrum of import oriented industries are available with our research organizations. On a long term basis, these

problems can no doubt be resolved, and the future patterns can be set accordingly. For the present we have to avoid the dislocation of existing industries due to the stoppage of flow of materials and technology without the creation of adequate indigenous resources.

Even with regard to the organization and continuation of the long term effort, the research organizations have neither the money or equipment, nor personnel to undertake work on a wide variety of problems. If, however, the better organized industrial units cooperated in setting aside part of their earning for research and development considerable benefits could be realized. The problem of research and development being often the responsibility of foreign collaborators would also need to be tackled.

An analysis of the industries, still open for licensing under the industries development and regulation act, would indicate a large area towards which research effort in this country could be usefully directed from a long term point of view even if no immediate returns may appear possible.

It would be fair to assume that somewhere in this country technical personnel who could make a possible contribution towards the realization of the objective of self-sufficiency invarious fields would be available. These experts, in view of the peculiar Indian situation, are often not assigned to the type of responsibility they are suited for. As time goes along, they become more and more isolated from their basic training and get oriented to all together new fields of activity. In many instances, various industrial organizations have their own qualified personnel, who could be assigned to research responsibility. The work of such personnel would normally benefit their own industries and not the country at large.

An important problem in the organization of a properly directed research effort to successfully tackle problems on a war footing, is that we must first of all determine all the points of major hold up in the important sectors of Indian industry, and narrow the requirement down to a few basic components and materials. Once we have realized this objective with the help, assistance and cooperation of various organizations in the country including the Directorate General of Technical Development, the task of assigning these problems to the various research organizatians in the country and finding suitable personnel either from our country or a large number of Indian experts working abroad would become relatively easier.

The Indian Standards Institution handles the standardization in various areas of national productivity. Their committees covering different fields, include in their membership, the representatives of manufacturers, Government organizations, Directorate General of Technical Development, research organizations and the large consumers. If these organizations and committees could be given the responsibility of finding solution to these problems, a truly great step forward could be taken. A sub-committee of these committees could be assigned to advise the various research organizations in this country on the specific problems of immediate concern. Tnere should be effective utilization of organizations that exist already. If this situation is brought home to the industries, there is no reason why this should not work.

Amongst the factors which we just cannot afford to ignore, are the serious limitations in research and development work on a broad spectrum of industries involving advanced technology. Industrial research

as such does not exist in India to any reasonable extent; where it does exist, it is confined to solving routine problems. From the point of view of immediate results, therefore, the best we can do is to locate a few areas well within the capabilities of the existing organizations for a concentrated attack. On the successful conclusion of these efforts, we can broaden the base of these activities to assure self-sufficiency in certain fields. A too broad or thin dispersal of effort at this stage, or our failure to produce the promised results within stipulated periods of time, would only hurt the national effort, and the confidence and image of our research organizations.

This is, however, not intended to suggest that the time for total assessment has not yet arrived. We should take every possible step to locate our bearings and set the direction for national effort. Charting out of a course of action does not mean the realization of the objective. It would, therefore, be necessary to assure that the progress of many industries which are way ahead of indigenous research effort is not throttled. In fact effort should be made to further the knowledge already gained through well directed effort within these industries, by the introduction of research scientists and engineers at proper places.

Another aspect of the problem of technological self-sufficiency which we cannot afford to ignore, is education. While a great deal may be said for and against the quality of technical education in the country at different levels yet it has to be admitted that during the recent years, some of the best students in the country have been moving towards technical education. While many of our educational programmes could use considerable improvement, yet in terms of technological and developmental self-sufficiency, some of our serious problems lie in the trends of post-graduate education. Thousands of our engineers and scientists are at present pursuing their studies in abroad.

The education of a very few of these students is oriented to the research needs of the country. In a recent survey by one of the important American universities, it was observed that quite a few of the foreign students from underdeveloped areas, including India were working on problems such as 'Structural and Thermal stresses in the nose cone of a Spaceship' as subjects of their post-graduate work. While from the point of view of these students, it will assure their getting highly lucrative jobs in the fast developing sectors of American industry, yet their proficiency in such fields has no relevance to the urgent needs of our country. It is not the intention to suggest that our students should not go abroad for training in advanced technology. There are hundreds of problems of technology where the contribution by our scientists and engineers could bring us closer to the realization of our objective of self-sufficiency.

Students going out of India, therefore, should be informed of the special research and production problems within their chosen fields. They should be made aware that the solution of these problems could contribute materially to the national needs as well as their own career in research or industry. Most of the students now become aware of these problems on their return to India on the completion of their training. Steps should also be taken to acquaint the students abroad of these possibilities. This could make an important contribution towards the satisfaction of our national needs.

In months and years to come, we should be able to direct the research and development effort of the country towards many of the problems that have been proposed before this Get-Together. It is also possible that as a

result of the situation now created, and with an organized attempt to solve these problems we may realize some satisfactory results.

The fundamental problems of the place of technology in serving the broad vital interests of this country would still remain. As indicated earlier, our basic problem has been, is, and will continue to be, the enlargement of employment opportunities in this country for large sections of our people. All the worthwhile objectives of setting up many basic industries and our journey into the realms of advanced technology would not even touch fringes of this basic problem.

It has been established beyond doubt that advanced technology has failed in expanding the employment potential even in countries like United States and is creating threats of large technological unemployment in the advanced countries.

Therefore, when we talk in terms of national development, how do we propose to satisfy this basic need. Another question that arises is, as to what is the type and level of technology that we should apply to the Indian situation, particularly, when the rate of obsolescence of advanced technology is far greater than its rate of acceptance?

It is, therefore, clear that the basic development problems of this country will only be solved through our own effort. Our problems in their totality have no parallel in history. We cannot accept partial solution from different parts of the world, nor can we afford to reject even the most advanced of technology from any source; but the integration of this technology with the needs of our country must be our own responsibility and should be done strictly in terms of our broad national interests irrespective of how much effort is required or how long it takes.

During the process of history, we have faced many a challenge. The basic concepts involved in the solution of many of these problems projected far beyond their times. In order to serve its true purpose technology needs a reorientation in terms of our wider interests. This can only be realized through our own efforts, outside the stiffling influence and oppressive glamour of imported technology, and within the basic and deep imbibing cultural foundations of our country.

Role of Cooperation between Research and Industry In India's Economic Development

Y.A. FAZALBHOY
Radio & Appliances Ltd
Bombay

Of the many lessons taught by the recent hostilities with Pakistan and previously with China the most important is the paramount need of self-reliance and self-sufficiency. For the past several years we have been building up our industrial base on a widespread scale covering every field of national life and aiming at production of goods and services and utilization of indigenous raw materials. But we must remember we have also been doing this with foreign cooperation and accepting foreign aid. Gradually we have also begun, more or less, to take such aid for granted as also foreign technical collaboration for know-how. Recent developments have shown us that international power politics can create very awkward positions for us specially at the time of national emergencies. Hence today's cry for self-reliance in all respects.

It is true that the dire need of the hour is self-reliance, but we cannot disregard the vital point that we have to couple this with development and progress. Self-reliance is the ability to be able to sustain ourselves within our resources. Development and progress alone will lead us to our cherished goal of a higher standard of living where illiteracy does not exist and poverty is a memory of the past.

In our aim to develop and progress we have to concentrate specially on three aspects :

(i) Food and other agricultural products are vital since the gap between production and the need of the teeming millions of our population is widening. We have to accelerate the rate of increase in food production in order to keep pace with the demands resulting from a rapid growth of population and the higher purchasing power generated by the development programmes. A crash programme to increase agricultural production is the only solution to this problem. We have to attain maximum self-sufficiency in this sphere.

(ii) The country's need is to have a strong, well-equipped defence force which can depend on supplies from indigenous sources for food, arms and ammunition and other essential goods and services.

(iii) Equally important is the role of industries which help to advance our standard of living by offering greater means of employment, creating production for better living and help earn foreign exchange by widening the range of exportable products. This will also lead us to be independent of other people, that is to say, we must not only build up our own manufacturing but we must also make our own contribution to

technological knowledge. We must be creative. The engineer, engaged in production, the worker in the factory, the farm-hand in the agriculture and the scientist and research worker in the laboratories have all to face this challenge.

In our twin endeavour to achieve self-reliance and to develop and progress, I must emphasize that the research worker has a key role and an important part to play. It is he who must show ways and means of developing things with the available resources whether they are machines or machine tools or other equipment or even suggest how to develop articles of food or materials for our clothing and shelter.

How are we going to achieve all these:

(i) What we must do and proclaim is that we are aiming at and planning a technological revolution—a revolution that is sponsored both by the government and by the people.

(ii) In short, we have to broadcast that the industrial worker, the farm-hand and the scientist are in keen pursuit of higher levels of development and progress.

(iii) The aim of this revolution is to achieve greater, better, and quicker results in the development of our economy.

(iv) The objective of this army of revolt is to build up a mass movement of technological innovation and technical evolution.

(v) It is only then that we can bring about an upsurge in industrial production in the country.

(vi) The scientist and the engineer must make up their minds to solve all key problems of production.

(vii) The range of problems to be examined and solved will be from the smallest change in production techniques to matters related to the development of new materials, new equipment, new techniques and new working processes.

(viii) We should not be afraid of bringing about changes, big or small in our drive for development and progress.

(ix) If such a movement can be built up into what may be called development experimentation, this will have a far-reaching social significance inasmuch as the country will be entirely transformed, all efforts being devoted to self-reliance, self-sufficiency, economic development and national pride in achievement.

(x) The purpose of such a movement is not only to fulfil current production targets but even more important—we must catch up with the world's advanced technical levels and transform India's industrial face with greater speed.

The time has come for the great and growing scientific resources of the country to be exploited for the greatest benefit of the whole community. Research and industry have to be and must become part and parcel of each other.

Recommendations

(i) To achieve the above, I suggest that each laboratory should set up a Production Council for the projects they have on hand.

(ii) Such a Council should have as its members the scientist-in-charge of the project, one or two as the case may be, and the engineer-in-charge of the production of each of the units actually engaged in the industry which exists in the country and where actual production is going on. He should not be the owner of the factory but one of the qualified technicians in charge of production.

(iii) The membership of the Council should be made compulsory by law.

(iv) It should not be a Council merely in name but it should be a 'Council of Action'.

(v) The Council will immediately examine whether the project on hand in the laboratory is related to the production in industry in any manner. After such an examination, it would determine what modifications, if any, are needed to make it of optimum benefit to industrial production. As a result of this study, the Council shall charge the scientists and the production engineer to examine the production methods, plant layout, materials used and all other related subjects. In this study the Council shall have the power to co-opt a Cost Accountant, Work-Study specialists or other technicians to help in fulfilling the project taken on hand.

(vi) If the project on hand in the laborotory has no counterpart in the industry in the form of actual production of the related item, then the Director of the laboratory on the advice of and in consultation with the Scientific Committee of the laboratory must examine whether the project should be abandoned and further work on it deferred.

(vii) *Terms of Reference*

(a) To study and suggest changes in method
(b) To study and suggest changes in design
(c) To suggest new working procedures
(d) To suggest measures for effective utilization of scarce raw material
(e) To suggest measures for more effective utilization of manpower
(f) To suggest measures for cost reduction.

The idea of this 'technological revolution' is to achieve results in the quickest time because of the twin objectives of self-reliance and development and research. 'Research for research sake' may be a luxury which we can defer. The research worker in the laboratory and the industrial worker and the farm hand must have only the aim of production within the resources available. Everyone will have to be engaged in the task of finding out new techniques and new processes while production is going on.

The economic development of a nation largely depends on the creative and imaginative minds of its people. Those people with imagination and a creative aptitude can produce anything of significance, only by working closely with people who have to give it a commercial shape. To this end the 'Production Council' is the only answer.

As we achieve self sufficiency and become more and more self-reliant in one field or the other, the widest possible publicity should be given to these achievements. Merit awards by way of cash, certificates and medallions

should be offered and distributed as incentives and in recognition of achievements in a particular field. Everywhere team-work will have to be encouraged and every worker will have to be rewarded in some way or the other by recognizing individual achievement as well as that of the team. The scientist, research worker and production engineer, the industrial worker or the farm-hand, should all combine together. These are not the times for the silent worker in the laboratories who is engaged in examining and discovering things confirming experiments carried out elsewhere and publishing the findings in scientific journals the world over and to be studied in symposia and seminars. The time is for action. These are the the days of the technocrat. The technocrat will be in the vanguard of the 'technological revolution'. The government and the people are parties to this revolt against complacency and the laissez-faire method of work pursued hitherto. We have to come out of it.

The need of the hour is to bring about the fullest and real cooperation between the research worker and those in industry and agriculture.

Let us not forget that this will not only enable us to bring about self-reliance but also it will unloosen the creative forces which have lain suppressed as a result of too much dependence on foreign technical aid, collaborations, loans and other forms of assistance.

Increasing Effectiveness of Research for Industrial & Economic Development

P. C. MEHTA
Ahmedabad Textile Industry's Research Association
Ahmedabad

In the present national emergency, the problems of reducing imports, increasing exports, achieving independence in meeting defence requirements and increasing agricultural production have become intensified. Scientists can play an important role in finding answers to many of these problems. We shall need to explore indigenous raw materials to substitute the imported ones and where necessary adapt existing technology to suit the new raw material. More and more machinery and instruments will have to be designed and manufactured indigenously. We shall have to concentrate on increasing productivity, reducing costs of production and improving quality. In addition, new product development will have to be undertaken. Application of scientific method to the study of these problems is bound to yield handsome returns, since all these problems are essentially technological. However, to get maximum returns out of our investment in research, we need much more than competent, dedicated scientists and big research laboratories. We need an atmosphere of confidence. We also need more effective communications at all stages between the various agencies involved in the total process of perceiving a problem, finding an answer and finally implementing the research results.

A crisis of confidence

Let us consider first the necessity of creating a climate of confidence. The three important parties involved are: industry (private or public sector), research organizations and government. What are their attitudes to one another as can be seen from opinions either expressed or implied through actions? Industry feels that the research worker has little comprehension of industrial problems, that his work is too academic and that he wishes industry to invest substantial capital on the basis of half-baked or incomplete data. The scientists believe that Indian industry has a complex about the inevitable superiority of foreign research and technical know-how. They also feel that our industrialists are not giving a fair chance to our research when they expect the same level of detailed know-how from them at this stage as that available from the technologically more advanced countries with their several years of lead and experience. Importing know-how through foreign collaborations, with the added advantage of an internationally established name and goodwill is a much easier way than working with our scientists to develop the know-how and promoting the product. The research worker feels that Indian industry has taken the easy path for too long and far too indiscriminately.

At the Government level, in spite of our protestations of the value of research and the scientific method in solving some of our national problems, financial grants for even approved projects are slashed during the conduct of the project, often without adequate warning. Foreign exchange requirements for inescapable import requirements of approved projects are not fully met. Even when they are, sanctioning procedures are so involved that there is at least a two years gap between visualizing the need and actually getting it. In other words, we have either not given as much serious attention to the problems of research planning as they deserve or we do not have the confidence that our research organizations can deliver the goods.

Whether one agrees with these beliefs, attitudes and opinions or not, no useful purpose would be served in disputing about their rights and wrongs. It would be more purposeful to see how this crisis of confidence can be resolved and how a climate can be created in which there it a better awareness of mutual problems.

User's role in planning research

We saw earlier that many of the problems of import substitution, export promotion etc. are technological in nature. It seems reasonable that in the formulation of a research programme whose primary objective is utilization of its results the user should have a voice in defining problem areas and their relative priorities. This is not to deny the scientist his freedom to suggest and initiate research problems. Often, with his background of literature and training, he may be able to see future trends much more clearly than the user. However, discussions and consultations with the user will bring out valuable information regarding market needs and demands, raw material availability, engineering and fabrication facilities required etc. about which the scientist may not be too well informed. Research projects selected in this way will not only be more viable in terms of current and potential needs and capabilities of the user, but the results are also more likely to be accepted and adopted by the user.

Another stage when the user can be usefully associated with the scientists is during evaluation of research results with a view to deciding whether they warrant scaling up to a pilot plant, and if so, what type of economic and engineering data should be obtained from this pilot plant.

Such a process of associating industry and research together at various stages of the project would increase industry's confidence that our research organizations are aware of its problems and are applying their expertise to solve these problems. Likewise it will enable the scientist to appreciate better what type of data and information an industry requires before it can accept a research finding and invest money into it. One may safely assume that industry would not be reluctant to accept a process or a product which has shown a reasonable chance of increasing its profits.

Should user pay for research?

Mutual consultation between research and industry is all the more important in our present set up in which the bulk of our research effort is financed by government. Industry does not pay for it, has no say in its policies and very likely, as a consequence, has no interest in it. A thing which is given free or cheap tends to be under-rated and its value equated with the price paid. Encouraging industry to bear at least a part of

the expenditure on research, at any rate utilization research, through sponsored projects, formation of cooperative research associations etc. would also promote greater interaction and confidence between research and industry.

The scientist as a consultant

In promoting industry's confidence, another useful approach would be to spend a part of the staff resources of the research organization in undertaking consultation services for industry. Instead of frowning on this work as not strictly research, it should be encouraged to a limited extent to give an opportunity to the scientist to be intimately familiar with existing industrial technology. Thereby the scientist can appraise better the scope for improvement as well as demonstrate to industry the benefits that can be obtained by applying an analytical and scientific approach to problems. Industrial development is not exclusively or necessarily the discovery of new processes and products. It also includes improvements in existing technology to increase production, improve quality and reduce costs, all of which are important for our export promotion drive.

Allocation of resources for research

Once a research project or programme is approved by industry and the research organization as worthwhile, the Government should examine its financial implications, including the requirements of foreign exchange, in relation to the potential benefits of substituting imports, promoting exports etc. Demands of various projects should be very carefully weighed in terms of total money available for research, the relative magnitude of the problem involved and the value of the potential benefit expected from the research project. Only in this way can disproportionate expenditure on research in different industries and problems be avoided. Where applied research is undertaken by an industrial organization, as in many countries abroad, industry plans its research expenditure on this basis. In our country, Government bears the major burden for research. This herculean responsibility must therefore rest on Government. Having once approved a project, the required money and foreign exchange should, as a rule, be made available to it promptly. It is much better, at the start of a project, to regret inability to support it financially, than to starve it when it is half-way through either because it was not examined with sufficient care at first or because too many projects were accepted for the total available resources. Not only does this practice lead to frustration, disillusionment and serious hardships to the research worker and his organization, but also money spent on uncompleted projects is more or less wasted.

Selling applied research

Turning now to the need for better communications between research and industry, one must appreciate a fundamental difference between basic and applied research, which calls for a totally different outlook on the method of communicating the results of research. Basic or fundamental research is essentially an intellectual exercise which one wants to discuss with one's peers through publications in learned journals. Applied research on the other hand, is meant to be used. However brilliant it may be, it loses its value, at least currently, if there is no one to use it. Even at the cost of repetition, it should be emphasized that applied research, unlike basic research, is not an end in itself. It is meant to be used. However good it may be, it is of no value unless and until it is used. Therefore, all the

modern methods of communication must be employed to bring research and its user together and to convey to the user effectively what he gains to benefit from research. Applied research cr ates a product, not a concept. Like other producers, the research organization must also accept the responsibility of selling its products.

Communication of applied research accomplishments is thus very similar to a marketing operation. One must ascertain the content of the message and the likely audience to which it is addressed. The language, form and vehicle of communication have then to be chosen for maximum effectiveness. Scientific papers, suitable and stimulating to other scientists, may not evoke any interest from industrial managers. Keeping the 'Guts' of the message unchanged, one must plan the form and the content in such a manner that it will first attract the attention of the particular people in whom one is interested, and then convince them of the value of the message to them. Such communications need not always be written—as a matter of fact, only a small fraction of written communications is actually read. Full advantage should be taken of oral and visual communications through talks, meetings, demonstrations, exhibitions etc.

Summary

To summarize, a much closer association needs to be developed between the three major partners in the enterprise of applying research for economic and industrial development. These partners are government as the financier, research organizations as the producer and industry as the user. Research planning would bemore purposeful and productive if allocation of available resources was based on relative importance of different industries in the national economy as well as the scope of potential benefits visualized from particular research projects. Continuation of financial support needs to be assured for approved projects throughout their duration. Methods and means of communication between research and industry must be planned according to the specific needs of the situation, so as to put the message across most effectively. The present Get-Together between Research and Industry is a valuable step in the right direction. One wishes that more time had been available for intensive discussions in small groups and hopes that this will follow as a sequel to this first 'meeting of minds.'

Cooperative Research And Industry

C. S. RAMAKRISHNAN
Hindustan Ferodo Ltd
Bombay

It is not the purpose of this short paper to discuss the necessity of research for furtherance of industrial development, for there can be nobody of responsible and enlightened men, who can be in any doubt, especially after the part played by scientific research during the war years. However, it may not be out of place here, to just mention, by the way of example, that but for the intensive research, during and prior to the war years, on the development of artificial rubbers, their processing and their behaviour under different conditions, and on the physical and engineering properties of these materials, both natural and artificial, which resulted in having the right materials, for the diverse applications of elasttomeric materials, the story of the war may have been different. Similar experience in other fields would also exist.

This paper demonstrates the type of organization suited to the environments and needs of our country especially in the present emergency. To begin with, we shall consider very briefly the organization of industrial research in the highly industrialized countries of the west and see how we may use to advantage such experience.

The organization of industrial research in the west falls broadly into the following classes:

(a) Industrial laboratories organized by individual firms

(b) Industrial research in universities from endowments by individuals

(c) Cooperative research laboratories organized by industry in conjunction with the scientific and industrial research departments of the State

(d) Investigations by the department of scientific and industrial research in its own stations

(e) Consulting laboratories.

The first of these types presupposes the existence of large financial interests, who could afford to finance the organization. It is by far the largest type in the United States. Similarly, industrially endomerd research is also carried to a large extent in the States. The main question is finance and scientific personnel, and if these two are in abundance, as in the States, the tendency is to have industrial research by the above types of organizations.

The working of the former type of organization will be limited to the particular limited field of the firm and the results even if it is of wider interest may not be readily available to the industry as a whole. This is of particular importance at this juncture when all developments leading to a saving in foreign exchange, by substitution of locally available material, to be full use to the country must be readily accessible to all in a particular industry. Some of these substitutions may require the services of scientific personnel and the use of equipment for evaluation which by their very nature will be considered unnecessary in view of their limited use by any single organization. Because of these limitations, although development of better products wlll depend upon the individual firm's endeavour, at the present juncture, it does not appear to be the most profitable line of action, when viewing any industry as a whole and from the point of view of country itself.

University research by its very nature should be a comprehensive research on all fundamentals of theoretical as well of possible practical applications and should be pursued without being curtailed in its scope and should not be expected to deal with immediate problem. It is to be considered as an insurance to mature in the course of time to the development of better materials and techniques of the future. It has the advantage over the former inasmuch as it could draw upon the technical knowledge and equipment available in the different faculties of the universities and could achieve results without duplication, provided the researches carried on the universities are carefully coordinated by bodies, such as Research Councils. The limitations imposed by the present emergency require other type of research organizations which combine the facilitles discussed above, but, at the same time will have impact on the present day to day needs of the industries taken as a whole. Among these will be research by the State under the department of Scientific and Industrial Research and Industrial Cooperative Research Laboratories organized by firms interested in particular flelds, and in conjunction with the State.

These two types of organizations have been in operation for the last 40 years in the United Kingdom. The Department of Scientific and Industrial Research has directly under its control 14 research stations, while there are 34 research independent associations under its agencies, serving different industries and 3 independent research organizations organized on a cooperative basis. The 14 research stations under its complete control are financed entirely by the Government while the 34 research associations which are autonomous bodies are financed by the industries directly concerned and by grants from the Department of Scientific & Industrial Research (DSIR) related in amount to the sums raised by the industry. Among these research associations one of the oldest pertains to rubber. Research Association of British Rubber Manufactures inaugurated in 1919 under the aegis of the DSIR.

Having given a picture of the organizations of research especially in the United Kingdom, we shall next see, how the type of organization referred to as Cooperative Research Laboratory, in which, the Industry and the State take part is best suited to us in this country. I am sure, representatives from the department of Scientific and industrial Research have their own plans to direct research into fruitful channels during the present emergency.

In a country like ours, where majority of the manufacturing units are comparatively small and cannot employ sufficient scientific staff, the

cooperative method of research, in which each individual member contributes a small sum towards the establishment of a central research laboratory and thereby makes himself eligible to the fruits of research work carried out, at a fairly high cost is the only method by which they can keep abreast of the modern industrial development.

Many of the problems, such as raw materials, essential auxiliary chemicals, the import of which was relatively free till recently, are common to the different forms in the same group. Therefore, import substitution by materialwise could be readily experimented in a centralized laboratory and the broad lines developed could be modified to suit the individual needs of the firms without going through the entire wide spectrum of possible raw materials and auxiliary chemicals.

Further, the central laboratory can help in the development of rational substitutes that could be manufactured economically because of the large demand created by the research, whereas single raw material and auxiliary products of use by one or two firms may be uneconomical to manufacture because of the limited demand. The development of new substitutes may further demand modification of techniques and these could also be developed in a central laboratory for the groups of industry as a whole.

Moreover, India lacks sufficiently trained scientific personnel and if they are to be utilized to the best advantage, a centralized laboratory serving particular industry as a whole, instead of a sectional interest, will lead to the development as a whole. Moreover, it has been amply realized in the past, that if any industry should move from development to development it should carry out research on the fundamental characteristics of the materials it is dealing with, in order to understand and their behaviour and to further their utilization in the best possible manner and open up new avenues of development. This exemplified by the fact that even industrial laboratories organized by private firms in the state, like Dupent, have undertaken fundamental research on fibres and like materials which have resulted in better fibres and other products. But fundamental research often needs much, patience, time and money, to cope up with. which situation even a moderately large industrial undertaking might find it difficult. Further, to get results that can be successfully applied to industry, an army of scientific workers specialized in different branches of science and technology is required, since a successful solution of a problem will necessitate a study of its ramifications. A centralized cooperative research laboratory can bring within its fold sufficient number of scientists, specializing in different fields and conduct research in a fairly big way and in this way serve adequately the industry with the small number of well trained scientists. The centralized cooperative research laboratory by procuring the small number of experienced research workers and by providing permanency of feaure provide for continuity of research programme, which may well last for years. A centralized laboratory by avoiding duplication of costly equipment and auxiliaries like library and workshop, will create economy, in these days of economic crisis.

From the foregoing it should be evident that the immediate establishment of cooperative research centres for such sections of the industry is essential. These laboratories could be well equipped, if necessary, at the first instance, with all the equipment that the industry as a whole needs for its development, by imports. This will save a lot of foreign exchange if each unit tries to set up its own laboratory which in any way will not be fully occupied. These laboratories then can fabricate necessary equipment for each of the industrial units in the light of the

experience gained. We would like to go further and say that each of these research centres should survey the available equipment and facilities in the different state laboratories and universities and avoid duplication by using their services and equipment whenever they are so that no equipment lies idle and is fully utilized. In this way they will not only give to the industry the benefits of such work without the units being unduly penalized by levies and other dues to finance the purchase of the equipment, but they will also bring to the universities and scientific institutions, the breeze of practical experience which will go a long way in breaking the barrier between purely scientific thought and practicability of technological approach. They will be enthused by the awareness that their abstract knowledge, sophisticated instruments, are no longer adornments to the institution but of immense practical utility.

It is very necessary before embarking on such a project to have a clear picture of what such a cooperative research centres should aim to do and what it will be detrimental for it to attempt. To benefit the Industry as a whole, the cooperative research centre should undertake the following work:

1. Fundamental studies relating to materials and processes
2. Studies of raw materials and substitutes
3. Improvement of standard processes and methods
4. Introduction of testing procedures
5. Improvements of standards of products
6. Studying the service requirements and fitting the products for the same.

Development of Indigenous Technical Know-how

S. S. MEHTA & S. S. NADKARNI
Industrial Credit and Investment Corporation of India
Bombay

The last fifteeen years have seen a substantial growth in the industrial field in India, characterized by the birth of a number of industries manufacturing products and using processes new to this country. What with the urgency of achieving targets within the time limit of a Plan, the need of making the best use of scarce materials and obtaining quick yields on even scarcer capital, this growth could not be based on the sound foundation of indigenous technical know-how. For this rapid growth, we had to pay the price of dependence on technology borrowed from foreign collaborators. Development of indigenous technical know-how, like all scientific achievements, is necessarily a matter of gradual, step by step progress. Since achievement of a satisfactory level of indigenous technical know-how is bound to take some time, it is all the more necessary to take early steps to attain this objective. A price will also have to be paid for this attainment; there would be mistakes made and there will be wastage of time and materials and there will be disappointments, but this would be a small price to pay for providing a proper basis for our future industrial growth.

We in ICICI, which is closely connected with the progress of industry in the country, are vitally interested in the problems connected with development of indigenous technical know-how and its industrial application. The ICICI has granted financial assistance to over four hundred projects in traditional and non-traditional industries; some implemented with foreign technical collaboration and others without. We have had opportunities of discussing the problem of technical know-how with major investors and technicians in industries and it is the purpose of this paper to share with those attending the Conference, our understanding of various aspects of technical know-how and problems connected with its indigenous development and its application in industry.

The foreign technical collaboration arrangements have had their advantages and disadvantages. They have been useful in accelerating our industrial growth and in certain cases, introducing up-to-date processes and modern management techniques. On the other hand, in majority of the cases, they have not imparted the basic product design and process know-how to our technicians, thereby perpetuating or extending our dependence on these arrangements. It may be advantageous and justifiable to take recourse to foreign technical collaboration arrangements for an initial project, but the necessity of repeating them the second and the third time indicates that we have failed in taking the best advantage of these arrangements and receded from the goal of developing our own indigenous technical know-how. An analysis of the various aspects

of services expected of and supplied by collaborators in the past is useful in deciding the necessity of such full-fledged arrangements or at least in restricting them only to selective aspects in future, thereby giving a fillip to the development of technical know-how in the country. This examination of the 'structure of technical know-how' is essential for appreciating the problems of developing indigenous technical know-how and for suggesting useful steps in that direction.

Structure of technical know-how

An analysis of the 'services' included in technical collaboration agreements shows that they fall into the following broad groups, which could be considered as the elements that form the structure of 'technnical know-how'.

(*a*) *Feasibility studies*, which cover evaluation and choice of a process based on availability of materials and utilities, examination of the nature of demand for the product and consumer problems and estimation of commercial profitability of the project.

(*b*) *Project engineering*, which includes selection of site and preparation of site developments scheme, preparation of layout plans and basic structural designs, drawing up of detailed specifications for equipment for inviting tenders, selection of equipment, supervision of erection and commissioning of equipment and coordination of various factors involved in implementation of a project.

(*c*) *Product know-how*, which covers design or formulation of a product.

(*d*) *Process know-how*, which covers data regarding materials to be used, operating conditions and production and testing methods, supply of tooling and training of personnel in using the techniques.

There is, of course, the last important aspect of manufacturing licences (covering use of patents, trademarks and brand names), which has recently become the subject of nationwide discussion. As this is not the place for a discussion on this subject, the following remarks are confined only to the remaining four factors.

Role of feasibility studies and project engineering in development of the technical know-how

To a science worker and a laboratory researcher, technical know-how is likely to mean only the product and process know-how, but it should be appreciated that the other two aspects, feasibility studies and project engineering are of vital importance for translating the laboratory research work into the industrial use, which alone can bring it to the level of fully developed know-how. It is our feeling that the neglect of these two aspects has been mainly responsible for non-utilization of a lot of research work carried out in our national laboratories.

Feasibility studies. Feasibility studies can be useful in more than one way in development of technical know-how and its industrial application. These studies, as they cover estimation of commercial profitability of schemes, can be used to measure the importance of a particular research project to industry. These studies can thus be used for deciding which of the projects can be profitably taken up for research.

At present, the results of work done in laboratories are published in technical journals which interest only a certain class of people in research

organizations and universities; they hardly reach those, who make investment decisions in industry. If the results are evaluated by preparing feasibility studies giving commercial profitability of processes developed, they would generate interest and initial confidence in industry regarding such work. Now the research organizations and industries speak different languages feasibility studies can break this communication barrier.

Certain products and processes developed may not be commercially profitable and yet these could have certain national and strategic importance. Use of aluminized sheets instead of galvanized sheets could be an example of such case. The feasibility studies in such cases would be useful in pin-pointing the reasons for adverse profitability, which would make it possible to initiate government action for instituting suitable preferential tariffs or for granting suitable incentives for making these processes acceptable to industry.

Many new and otherwise economic processes and products have languished because of consumer problems. Development of nickel-free stainless steel would be hampered unless difficulties connected with its fabrication are overcome. A study of the nature of demand and connected problems, which should be a part of the feasibility studies would be helpful in bringing such problems to the research workers, who can suggest solutions to these problems or modify the processes and products developed to overcome these difficulties.

Project engineering. The importance of project engineering in the structure of technical know-how cannot be over-emphasized. A large part of the paid sum fees paid to foreign collaborators is for project engineering work. A traditional, well-tried process may run into difficulties in a particular plant because of indifferent project engineering, so the fate of a new process can easily be imagined, if it has inadequate projeet engineering support. A process backed by a strong project engineering set-up will be readily accepted with confidence by industry.

Development of organizations for carrying out feasibility studies and project engineering

As discussed above, the research work can be raised to the level of technical know-how only with the help of feasibility studies and project engineering. If the objective of development of indigenous technical know-how is to be achieved, it will be necessary to build up organizations for carrying out this work in coordination with research organizations. In view of the close coordination necessary, it is not inconceivable that this work could be also taken up by the research organizations, but this may not be possible because of the existing limitations on the personnel and finance available with these organizations.

In the public sector, a start has been made in building such organizations and a few establishments like central design bureaus of Hindustan Steel and Technical Consultancy Bureau at Delhi have already started functioning. But these organizations need to be expanded considerably, if they have to have any significant impact. What is of significance here, is that no attempt has been made to bring about a liaison between these organizations and our research establishments.

In the private sector, there are less than thirty organizations, which can take up feasibility studies and project engineering work. Some of the important ones amongst these have foreign affiliations and these cannot be

expected to have a positive bias towards technical know-how developed in this country. Other Indian organizations require considerable strengthening of personnel and they are in need of encouragement from Government. Here too, no step has yet been taken to interest these organizations in the work done in our research laboratorics and to utilize their services.

The CSIR can explore ways of bringing about a close liaison with these organizations, both in the public and private sectors.

Project engineering is one aspect, which could be considered immediately for elimination from or for inclusion only in a restricted way in future technical collaboration arrangements.

Development of product and process know-how

Development of product and process know-how especially to level where the country could be entirely self-reliant in this regard is bound to take a considerable amount of time, despite a lot of wishful thinking. No miracle can be expected in this regard. This long term problem connected with the paucity of scientific and technical personnel, difficulties in attracting them to research work from more lucrative production jobs, low level of research expenditure, lack of research bias in educational system and dearth of research facilities in universities have been discussed often. It is not proposed to go over these problems again in this paper, but we wish to consider here certain steps that could be immediately and profitably taken to obtain certain quick results in this field.

Concentration of research resources

Our limited resources of personnel and finance compel us not to fritter our research efforts over a large number of problems. It is essential that they are concentrated on a few important problems either having potential of yielding large commercial benefits or those having national and strategic importance. What is required is not a large number of papers published by research organizations on a variety of problems, but persuing a few important ones to their complete solution including industrial application of the techniques developed. It would be necessary to select the problems carefully and industry would have to play a predominant role in selecting and formulating the problems.

Action teams for research on important problems

We find that certain useful research work on important problems has been carried out by our research organizations, but it has still not been commercially exploited for one reason or the other. An example of such a case is aluminizing of tubes on which National Metallurgical Laboratory has done some work, but no tube manufacturer has yet adopted the process despite the acute shortage of zinc used for galvanizing. We suggest that such problems, especially those of immediate importance be entrusted to Action Teams formed jointly of technical persons from research institutions, industry and any other connected organizations. What we are suggesting is not a committee working at a desk for going into the merits of the research work already done, but a set-up of technical people, who would carry the research work on these important problems further and take it to its logical conclusion. In the case of aluminizing of tubes, the action team may comprise connected research workers from NML, engineers looking after galvanizing plants of certain steel tube factories, technical staff from

primary aluminium producers and certain project engineers. If this basic idea is accepted, it should be possible to work out details regarding *modus operandi* of such a team, its administration, and financing of work done by it. Our discussions with some manufacturers of tubes indicate that they would be prepared to spare the necessary personnel and meet their share of the expenditure. It would be useful if CSIR could seriously consider the formation of such teams.

Research in industry

The importance of work in our research organizations and universities cannot be denied but it can never take the place of research and other efforts carried out in industries for developing technical know-how. At present, such efforts are conspicuous by their absence because of several reasons such as lack of competition which does not provide sufficient incentive for development of better products and improved processes for reducing production costs, ease with which foreign technical collaborations can be arranged and the reluctance to channel scarce capital towards research facilities, which can yield returns only over a long period.

With the growth of industries, the competition amongst various manufacturing units is bound to develop as it has already started developing in certain fields like electric meters and cables, wire ropes, glass sheets etc. Government is now becoming more and more alive to the need for restricting the extent of foreign technical collaborations. These factors may see wearing off of the first two existing disincentives for research expenditure in industries. Meanwhile, it would be useful, if Government considers certain fiscal measures and other incentives for encouraging research expenditure in industries as well as discouraging dependence on foreign technical collaborations.

Summary and conclusions

1. The last fifteen years have seen a rapid industrial growth in India characterised by birth of several industries manufacturing products and processes new to the country. For several reasons, this growth could not be based on the sound foundation of indigenous technical know-how and we had to depend on foreign technical collaborators. It is necessary to analyse the services covered by such collaboration arrangements, to examine the structure of technical know-how, for appreciating the problems of developing indigenous technical know-how and for suggesting useful steps.

2. Feasibility studies, project engineering, product know-how and process know-how are the major elements forming the structure of technical know-how. The first two are essential for industrial application of laboratory research work and for raising it to the level of a fullfledged process.

3. It is suggested that steps could be taken to strengthen the existing organizations in the public and private sectors, which can handle feasibility studies and project engineering work and to establish new organizations. A close liaison between them and our research organizations would be useful in bringing about industrial application of laboratory research.

4. Project engineering could be one aspect, which could be immediately considered for elimination from or only restricted inclusion in future technical collaboration arrangements.

5. Development of product and process know-how to a degree of self-sufficiency is bound to take a considerable time because of several reasons, but a few steps have been suggested for accelerating the pace.

(a) Our limited research resources could be concentrated on a few important problems selected in consultation with industry, instead of diffusing them on several small projects of academic interest.

(b) Action teams made up of research staff from our national laboratories and technicians from industries could be formed to continue research on important projects (where basic work has already been carried out by the former) with a view to developing them for industrial application.

(c) Government could take certain fiscal measures and give other incentives for encouraging research in industry.

Scientific Research for the Development of Indigenous Know-how

M. M. SURI
Central Mechanical Engineering Research Institute
Durgapur

India's vast resources of land, labour, minerals, water, power etc. promise us a great future. Yet after eighteen years of handling of our own destinies, at the end of the Third Plan, the much sought after 'take-off point' in our national economy is eluding us. The gap between the advanced countries and us has in effect been widening, unlike the case of a host of other nations, the Russians, the Japanese, the Chinese, or even the Egyptians. Each one of them is effectively closing this gap, while we appear to be sliding backwards with our shortages in food, inflation in money, and a general flagging of the economy. For these over-bearing problems now confronting us, it is my belief, if there is a solution, it lies only within the horizons of Science and Engineering.

It is obvious today that it is not enough to launch Five-Year Plans, or merely projects of crores and crores of investment. Such investments can help, as they actually have helped up till now, monetary inflation. Inefficient utilization of capital and large spendings with inadequate outputs can bring no other results. Each industrial investment must be a sound, scientific, and economic proposition not only when it is effected but in the foreseeable future as well. This implies more than mere planning. This implies research for continuous development of technology.

The Indian industry is basically a licensed industry. Initially, for immediate industrialization, there was and could be no other choice. A broad enough base has now been established in the past 18 years, of a very wide variety of heavy, medium and light industries spread all around this subcontinent. It is time for an assessment of the licenced industry and our continuing dependence on foreign know-how.

After these many years of working licensed industry, the cost of indigenous products continues to be unduly high and their quality poor. The reasons are much too apparent. The cost of setting up an industry with imported technical know-how, in an underdeveloped country, is far greater than setting up the same in developed countries. Most expensive is the delay between the time when expenditure has begun to be incurred till the industry's wheels set rolling, especially in India. Added to this, the uneconomic usage of the plants with relatively inexperienced managements and operators results in high cost as well as poor quality of indigenous goods both in public and private sector enterprises. Thus the listed price of indigenous products does not reveal their true cost to the consumer. The life expectancy may be less than half that of the imported components. Not only therefore is the true cost doubled, the consumer

demand is doubled too, causing artificial market scarcity. This is so far true for almost all indigenous products, motor cars, scooters, refrigerators, electrical appliances, steel or steel products. Under this apparent mask of industrial expansion, our shortages only grow and inflation increases. The intrinsic values have, and continue to escape our notice.

The hazards of continued dependence on licensed industry must be clearly expressed. When a licensed industry is established in India, the import of similar goods is perforce restricted. This implies that the state of knowledge and technical advancement is frozen at the level when the licence was obtained. Year after year, when this country imported goods, the latest, the most competitive products found their way into India. Each of these products embodied millions worth of research and development. Restrictions on imports indirectly bar access to these latest advancements. It is here that a real danger lurks in a planned economy, unless, immediately any industry is licensed and imports restricted, there is adequate and commensurate planned expenditure on research for that particular industry.

Obtaining licenses for know-how is no complete answer for an under-developed country. Licensing holds promise of gaining time, provided the pitfalls of licences, their merits and demerits, are administratively grasped with clarity. Most of us who have been responsible for working licensed industry, have felt that many of the licensed products or processes do not fully cater to our particular needs. Even the vastly different practices, for example, between the British and the American industries can often be explained by saying that each is doing a sensible thing in its own circumstances. The first requirement of a licensed product is its adaptation to Indian environment. This calls for indigenous research and development. And once research is commenced, with the basic level of technical know-how already obtained under the licence, indigenous talent will begin on the cycle of further discovery and innovation, of producing more with less effort, at less cost, of replacing imported materials by indigenous materials, of so-called radical discoveries, new products, and processes. I suggest, therefore, that it should be a necessary condition of setting up licensed industry, that commensurate expenditure on research and development sections is simultaneously planned and carried through.

Future of Indian industry, public and private, is not secure if they do not aim to: (i) lower costs of indigenous products through increased productivity, and improved designs ; (ii) lower intrinsic cost through improved quality ; (iii) create research facilities to develop indigenous know-how to limit foreign dependence ; and (iv) be self-generating through regular technological advancements year after year.

Without a deliberate and planned effort towards achievement of these aims, there can be no improvement in the lurking economic crisis. With the growing pressure of population, the ever-increasing defence budgets from which there can be no respite for the next ten years, and low level of food production, it is impossible to entertain optimism unless there is a radical change in the outlook of private and public sector investors towards research expenditure. When our resources are meagre, the need is all the greater to harness technical ingenuity through organized research and development.

The example of all countries that have made rapid progress within the past two decades is clearly before us. Most striking is the example of Japan.

Only a little while ago, the West could afford to sneer at the copying talent of the Japanese. Today all the highly industrialized countries recognize Japan to be their most formidable competitor in every field of engineering. World markets, including such competitive markets as USA, are flooded with Japanese goods.

Japan has worked no miracle. It is well-known that economic growth in the highly industrialized countries in the world is due entirely to advanced scientific research and technological developments. The expenses on research are deliberate and sustained. The expenditure on scientific research is also a sound index to the prosperity of any nation. Executives in India, in the public and private enterprises cannot within any wisdom, afford to overlook these clear lessons of scientific history. In spite of the fact that Indian industry dates back to over a hundred years, the expenditure on research has lagged considerably behind the investment expansion of the industry. As an index it may be useful to note that the USA and USSR spend over 3 per cent of their national income on research and developments, whereas India is hardly reaching the level of 0.32 per cent. Considering also the comparatively smaller size of the Indian national income, the total expenditure on research is insignificant. The research output is also therefore less than meagre.

The gravity of these figures could be better appreciated if it is noted that even in the Fourth Plan we will be aiming at an average spending on scientific research of 0.79 per cent only of our national income. This means merely Rs 3.4 per capita expenditure during the Fourth Plan ending in 1970–71, when USA was spending, as far back as in 1961-62, Rs 410 per capita. It is also interesting to know that China in 1960 was spending Rs 200 crores when India, even by 1961-62, had only reached a level of Rs 47 crores. These figures speak for themselves emphatically enough, and are clear indications of our scientific stagnation. The resultant economic crisis therefore does not surprise the scientific observers.

The desirability of the fullest and speediest application of science is commonly regarded as self-evident because it is today a condition of fitness for survival in this world of growing complexity. A country becomes richer by increasing the rate of exploitation per head of its population of its natural resources of materials and human labour, or by improving the manner of that exploitation so as to fulfil human needs at less cost. The use of science and technology is, from one point of view, simply the exploitation of the natural resources of brains to overcome the deficiency in other resources. In this sense, exploitation of brains is the necessary condition for increasing prosperity in a country which has large unexploited reserves of materials and labour. And India compared to China, Japan, or Russia is in no way inferior in its resources of brains. What is grossly lacking in India is, in one simple expression, the lack of a science oriented policy. We plan, no doubt, to spend on industry, on agriculture, power, irrigation, etc. crores of rupees giving inadequate thought to commensurate spending on research and development, which alone can ensure that these crores shall continue to bring in desirable financial returns.

It was generally believed in the past in the West, and is still believed in India, that scientific research cannot be planned, and increased allocation cannot decide the rate of growth and discoveries. It was considered that discoveries are unpredictable and cannot be foreseen or planned for. This is true. But what this truth hides is the other more important fact that though the actual discoveries could not be predicted, their rate and number

is determined by the funds made available and number of scientists employed. Further that the discoveries will be mostly in the field in which the funds and scientists are deliberately diverted. These two truths are demonstrably employed by other nations with clarity of action and positive achievements to their credit—and in the particular fields desired.

In an underdeveloped country, such as India, research and development need not immediately acquire the sophistication of the West, because the problems posed are not those of the highly developed industry. A very large number of problems are simple and elementary. To say the least, our industries are technically sorely sick and ailing. Their need is not so much for fundamental break throughs, as plain sound engineering, high productivity, and good quality control. Research and development activities, aimed at providing assistance to these simple ends, would bear immediate fruit. The type of research and development most urgently required is the adaptation of known sound practices in engineering, to local conditions of labour and environment in the day to day problems of our industry.

The Central Mechanical Engineering Research Institute, Durgapur, pursuing specifically the policies of the Director-General, Council of Scientific & Industrial Research, has within a short period demonstrated effectively what could be achieved through organized research, and how immediately, the national economy may be bolstered through increased investment in science. The impact of research investment on economy, especially flagging stagnating economy, is far greater than that of any other investment, both as regards immediate returns as well as future recurring savings. A few case histories would better illustrate this.

Cable-making machines were hitherto imported. The requirements of imports of these machines in the Fourth Plan are Rs 24 crores in foreign exchange. The progressive management of Hindustan Cables Ltd embarked upon collaborative research with CMERI for the indigenous development of cable-making machines ranging in price from Rs 30,000 to Rs 600,000 per machine. The inexperienced, but qualified staff of CMERI formed the central point of development, obtaining guidance from experienced technical hands of the Hindustan Cables who have years of experience with similar machines imported from many different countries. The engineers of the interested indigenous manufacturers, were also brought in to form a complete team. Each design of component/sub-assembly/assembly, when developed, was commented upon by the manufacturer to suit his local facilities, and then critically examined by Hindustan Cables engineers who have long and varied experience with foreign machines. The CMERI has had to develop special electronic controls from the very restricted range of indigenously available elements and labour with alternative indigenous materials. With the keen vigour of the young scientific staff, the constant encouragement of the experienced Hindustan Cables' executives, and the all out efforts of the indigenous manufacturers, Kumardhubi Engineering Works and Mc Nally Bird, the prototypes of some machines are already working. In the global tender opened by Hindustan Cables last month, Rs 1.76 crores worth of CMERI designed machines have been tendered. Another Rs 40 lakhs worth are to be tendered by February 1966. These cable machines have 98 per cent indigenous content, and as delivered to Hindustan Cables, they are lower in cost than the imported machines. This is *one* year's effort of *one* Division of CMERI. An estimated Rs 15 crores of foreign exchange can be saved within the Fourth Plan on cable-making machines alone. Indeed after

this demonstration of past efforts funds and facilities would have to be admitted for this Division, if Rs 15 crores of foreign exchange is to be saved. A sanction of Rs 20 lacks of foreign exchange, for purchase as samples of up-to-date available machines, could accelerate the pace of development to ensure achievement of this target.

Another striking example is the research undertaken for savings in steel for structures. The CMERI's structures, designed and fabricated from most readily commercially available sections of angles and bars only, have returned in every case, economies of over 30 per cent in steel compared to conventional designs. These fully welded open web designs comply with ISI specifications. They also lend themselves ideally to techniques of mass manufacture. The combined efforts of the Regional Engineering College staff and CMERI, with regular exposures to the experienced structural engineers of Kumardhubi Engineering Works, Jessops and Apeejay Structurals, have brought forth perhaps the most impressive and far-reaching economies demonstrated by the following constructions already undertaken.

Name of user	*Usage*	*Compared to*	*Saving through CMERI design*
1. CMERI	Technological Block No. 1	HSL Technological Block	43%
2. CMERI	Technological Block No. 2	HSL Technological Block	over 50%
3. Heavy Electricals, Bhopal	Storage Shed (with 5 ton cranes)	HEI's own designs	over 50%
4. Kumardhubi Engng Works	Structural Shop (with two 20-ton cranes)	KEW design	over 40%

It is a noteworthy fact that this rather simple design concept of CMERI, with most easily available angles and bar sections, is lighter and cheaper by no less than 20 per cent on an average, than the tubular constructions generally favoured for reducing weight of structures. In India the shortage of tubes is, and shall continue to be acute, while angles and bars are easily available. Thus a shift to the new design is very rewarding. It uses less steel than even the tubular construction, availability is assured and the cost of the structures is substantially lower than tubular or conventional designs.

Nationally applied, the returns possible from this research programme are easily calculable. In the Fourth Plan approximately 5 million tonnes of steel will be required for structures of which approximately 50 per cent represents light structures for factories, roof trusses, single beam columns and other buildings like store houses etc. an area most easily covered by the present researches for an assured minimum 30 per cent saving equalling 0.75 million tons of steel valued at Rs 60 crores. The reduction of investment of completed structures is valued at Rs 100 crores minimum!

Of the balance 50 per cent required for medium heavy and heavy structures of workshops, steel plants etc. there could be similar savings provided design development work could be initiated without any loss of time. Given the full support of public and private sector administrations, a total saving of Rs 200 crores is not outside the scope of this research

programme, representing 1.5 million tonnes of saving in steel worth Rs 120 crores. This could in fact be a saving in foreign exchange since Rs 500 crores worth of steel is expected to be imported to meet the gap between demand and supply of steel during the Fourth Plan.

The CMERI and Structural Engineering Research Centre, Roorkee are jointly preparing to meet the challenge that may be thrown at them once the importance of present researches is nationally grasped. Needless to point out what immediate Governmental backing with funds and facilities, with a few lakhs of foreign exchange release, could do in this matter to achieve national economies.

Besides these two examples there are numerous other research projects with CMERI in various stages of completion, including those for indigenous scooters, tractors, turbine pumps, automobile radiators, automotive filters, refrigeration plants, industrial ice flaking machines, shear-punching machines, electronic comparator, electronic balancing machines etc., aiming similarly at many crores of savings in foreign exchange during the Fourth Plan itself, besides generating effectively self-sufficiency through self-reliance.

In all these projects the young, keen, qualified, though relatively inexperienced scientists, are combining their talents with the experience available within the country in the manufacturing units, with actual users, the university professors or visiting experts. In substance it is simply that, if there are young minds engaged in scientific work, and if objectives and targets have been clearly laid before them, given reasonable facilities, their performance and output would more than equal our national aspirations.

At this stage something has to be said in defence of past performance of Indian research. People speak of the sums already expended and the meagre results. It has already been pointed out how meagre, and considerably below the floating level has been the spending on research till now, which means that the Government was not depending, in effect, on organized research which produces tangible results within forecasts of specific time horizons, but rather, on the flashes of stray genius. In USSR over 2000 institutes of applied research are in active harness with staff strengths from 300 to 3000 in each institute. With more than thrice their population, we have fewer than one-hundredth of their strength engaged in applied research!

The mechanics of applied research do not appear to have been effectively grasped, or followed in India. The successful conclusion in the laboratory of a piece of research, is often to be followed by setting up of a pilot plant, in which the problems of full scale production can be studied. Thus the mechanical engineering research might begin with a designer who is a highly original creator of a complex product. He has then to be assisted by a Development Engineer capable, within the broad framework of the design, of dealing with the practical problems which arise during the process of development. He is practical but not necessarily an original thinker, with good judgement and an idea of costs as well as engineering possibilities. This is then to be followed by a Production Engineer, who is concerned with the practical problem of tooling up for particular model for production, before the fruits of research expenditure become manifest.

In the particular case of the Indian research, it is not the basic lack of good scientists or original thinkers, nor the lack of potential development

or production engineers, that has disallowed the creative genius of this country to surface; it has been lack of proper and organized tie-up between these various individuals of the required background and discipline to form the team in a manner found essential for organized research. Till now, it is apparent, that some of the links remained to be forged, because of which scientists in laboratories could not communicate their ideas in a way in which industry can understand or use them. The deficiencies are fast being overcome within and outside the CSIR, to the extent funds made available make it possible.

With these links effectively forged, between CSIR laboratories, other laboratories in the country, and the private/public sector industry, the Fourth Plan could largely be fulfilled with the limited foreign aid now expected, provided we approach the problems in a scientific manner, with clarity of vision, and indeed, determined action of the Government which alone can provide this crucially urgent leadership. The Annexure outlines a few of the areas surveyed by me in which drastic reductions in foreign exchange are possible for the Fourth Plan. This is an indication of what a nation-wide survey with the help of scientific institutes and their related industries could reveal! It is important to state that the Indian engineering industry today is *not* working beyond 25-30 per cent of its installed capacity. Increased indigenous manufacture in replacement of imported goods would throw upon it a load that it can absorb, leading to better economic returns from past investments. Most of the industry is working one shift only, and in some cases 1½ or 2 shifts. Indigenous designs and indigenous materials are urgently required, which only a concerted indigenous scientific effort could provide. The country could then look forward to fully self-sustaining economy before entering the Fifth Plan—provided the Fourth Plan is, from now on, adequately research-oriented.

There is another most important consideration. The application of science to industry and returns from ingenuity and inventions are not dependent on the scientists alone. Any survey would reveal that important new developments frequently begin from the vision and drive of one man or a small group of men, both in small and large undertakings. There are far too many occasions when without a change in technical staff, market situation, or financial conditions, the arrival of a new man to a key position changes the entire aspect of the industry and its progressiveness down the line. This has led observers to conclude that progressiveness depends greatly on the key personalities, and that an unprogressive undertaking can be made progressive by changing the quality of the key personnel. Placement of progressive personnel in key positions, in public and private sectors, is the most essential prerequisite for utilization of Indian scientific research. This alone may retrieve the Indian economy from its impending crisis.

In the end, it is to be recognized that given all the keen talent, the total research output is limited by the number of qualified men, the equipment, and the funds plied into developmental research. In a country as vast as India, with a complex of private and public sector enterprises spread all around the country, the government effort ultimately can only form a small part of the total research and developmental effort. Each leading industry, public or private, must organize and establish its own research and development cells which can collaborate between themselves and with the other established institutes. Without the industries own

research and developmental cells it is difficult for them, and still more difficult for others to identify and define their problems. The developmental cells attached to industries alone can use in a big way, the available resources of the various Indian institutes, their researches and innovations. A sizeable research and developmental effort in the country can be organized only in this manner leading to a self-generating economy with continuing advancements, year after year.

Based on experience around the world, it can easily be estimated that unless a deliberate expenditure of Rs 700—800 crores is incurred on research and its applications in the next five years or so, the country should not be surprised, at the end of this period, to find its economy still tottering and the nation groping for the much sought after 'take-off point'. Adequate money must be spent on research and research utilization, otherwise further investments in Fourth Plan of the order of Rs 20,000 crores may only sink our solvency and increase our national indebtedness.

ANNEXURE

Self-sufficiency can only be generated out of self-reliance, determined by the will of the people to do things themselves, a will which must be reflected in greatest measure in the will of the Government to do it ourselves, which in the past has not been so evident, and which it is feared, may still not penetrate through the red tape effectively enough, even though the Governments, policies are veering towards self-confidence, self-reliance, and self sufficiency.

The following are the principle reasons why imports have been heavy in the past :

(i) Ease with which foreign exchange has been made available to the public/private sector industry. The only difficulty has been in completing paper formalities and paper checks.

(ii) Lack of knowledge with purchase organizations regarding what is available in the country. There are no reliable directories or purchasers guides available in the country, while new industries are coming up all the time all around this sub-continent.

(iii) Lack of available designs to load up spare capacities, and lack of design development organizations both in the public and private sectors.

(iv) Lack of emphasis on indigenous research and a drive to develop or utilize Indian technology, or rely upon Indian engineers.

If examples explained in the paper are extended by forming active teams and team leaders—not part time Study Groups—and tasks assigned, engineers/scientists are available with CSIR, public and private sectors, who can reduce the foreign exchange requirements to at least the extents shown below. These have been gauged by my colleagues and myself in preliminary studies of only a few fields. A nation-wide survey through nominated team leaders could, reveal much greater scope for use of indigenous capacity, indigenous materials and indigenous technology, of which we now see every day many commendable examples at the level of individual entrepreneurs ever since present foreign exchange crisis has occurred.

Capital Investment in Fourth Plan Industry

(Rs crores)

Item	Estimated investment Total	Estimated investment F.E.	Possible savings F.E.
1. Iron & steel, steel ingots, finished steel, pig iron	1082	457·5	200
2. Alloy, tool and stainless steel	114	54	20
3. Aluminium	140	65	20
4. Non-ferrous-Cu, Zn, Pb	76	28	8
5. Steel structurals	38	12·75	6
6. Cranes	10	2	1
7. Cast iron rolls	15	5	4
8. Road rollers	2·5	0·5	0·5
9. Other road & construction equipment	10	4·0	2·0
10. Motor cycles & scooters	7·5	2·5	1·75
11. Auto ancillaries	25	8	5
12. Tractors	23	9·5	7
13. Cables & wires	65·5	24	15
14. Fertilizers	306·3	134·4	50
15. Petrochemicals	121	56·3	25
16. Paper & pulp	150	55	25
17. Synthetic fibres	50	20	5
18. Coal production	185·35	51	15
19. Iron Ore	50	16·5	6·5
		Total	416·75

Maintenance Imports

	Saving (Rs crores)
1. Steel (from 500 crores)	120
2. Alloy Steels NML/CMERI/ASCON (from 150 crores)	10
3. Aluminizing instead of galvanizing (even if aluminium is imported)	10
4. Fertilizers, Potassic (from 58 crores)	15
5. Fertilizer, nitrogenous by shift of emphasis (from 134 crores)	30
6. Rayon pulp, paper pulp (from 69 crores)	20
7. Automobile, motor cycle, scooters (from 182 crores)	60
8. Auto-spare parts & equipment for garages (from 40 crores)	10
9. Railways (from 100 crores)	20
10. Components for machinery industry (from 561 crores)	110
11. Maintenance spares for machinery industry (from 360 crores)	65
12. Hides and skins	5
Total	475

The foreign exchange savings can be divided into two groups, viz. Capital Investment and Maintenance Imports as shown above.

A saving of Rs 475 crores in maintenance imports is not a difficult task considering that the Fourth Plan estimate of such imports is estimated at Rs 5500 crores.

Thus from preliminary surveys an approximate total saving of foreign exchange of Rs 415·85 crores in capital and Rs 475 crores in maintenance imports, i.e. a total of approximately Rs 900 crores is not beyond the capacity of properly harnessed available indigenous talent.

Applied Research Related to Materials and Product Control

AUDUN OFJORD
Central Mechanical Engineering Research Institute
Durgapur

The greatest problem of Indian economy in the present development of the country seems to be that of industrial dependence on imported materials, know-how, and sophisticated machinery and equipment. It is natural that such circumstances will give a licensed industry which is at a considerable handicap when it comes to producing quality products at low costs, in comparison to its competitors in developed countries. Another factor contributing to such high costs and often inferior quality is the lack of a sophisticated industrial environment with highly skilled and experienced management, technicians and labour. The latter condition is particulary valid for the 100 per cent indigenous industry at least in its developing stage when the proper designs for the product must be carried out, the materials chosen and specified, the production apparatus and facilities acquired and installed, and the production itself is to be started.

In order to improve the economy of the country and achieve future independence it is essential that the talents of the manpower within the country and the natural resources at hand, are fully utilized for a common cause, namely that of increasing the standard of living of all its inhabitants. To approach this end, an important tool is that of full utilization of the present research and development facilities in the country.

That a country is industrially independent does not mean that the country is blessed with all the raw materials needed in its varied production, neither that all the machinery for its production must be produced within the country itself. It only means that with an adequate supply of all needs, the economic balance between exports and imports is maintained. The most prosperous nations are, of course, those which have greater exports than imports.

In order to solve the problems of balance between supply and demand, one must look at the sources of supply and solve the problems related to making this supply adequate. India has food shortage for its 480 million people. The agricultural output is however considerably below the capacity, and with proper fertilizers, tools and irrigation facilities, not only could the demand be met with, but exports to balance essential food imports could also be achieved. This and other related problems must be approached in a scientific as well as a practical manner, and this requires joint efforts by the farmers, the scientists and the industrialists.

Having given this short introductory remark I will, in the following, be more specific in regard to a few problems which when adequately solved, will definitely contribute towards industrial independence.

Materials

India has today a vast number of licensed industries dependent on imports of foreign manufactured parts, machinery and materials. It is possible that even when fully developed India will still import some of these items, but only if it is the most economical thing to do. Today, however, some of the imports, particularly regarding materials, is poorly justified.

One of the conditions stipulated in acquiring a licence for a particular product is that the materials must be supplied to certain specifications. Such specifications are usually corresponding to a standard materials available in the country of licence origin, and can seldom be in complete agreement with the specifications of corresponding Indian materials. In such cases, the easiest way out, and this is often the most expensive, is that of importing such material.

It is a known fact that a vast variety of materials, the number of which is ever increasing, are introduced on the world market today. Each one of these conforms to a particular specification, and very often will this same material also conform to a previous specification issued for a different material or in a different country. It is thus an almost impossible task to make sure that an import licence given in such a case is fully justified.

I have recently learnt that a few sensible industrialists have surveyed some of the Indian requirements regarding carbon steels and alloy steels. In spite of that a great number of foreign and Indian specifications are quoted for these requirements, 90 per cent of the requirements can be met by only six different grades of steel. The specifications are given with maximum and minimum chemical contents and one must study the various specifications in order to discover the possibilities of great rationalization. The industrialists mentioned have formed a consortium which will manufacture these steels by utilizing spare capacity in present industry. The example stated is mentioned only to show that there are possibilities of utilizing research facilities in India to undertake studies of similar nature in order to minimize the number of materials which will replace a greater number of previously or presently imported ones. This kind of undertakings will not only save foreign exchange, but will provide the manufacturing industry with materials which will become rapidly well known to them, thus bringing about a condition which any manufacturer will welcome.

In the early days of the development of plastics, these materials were primarily developed in order to replace certain materials of scarce availability. Later it has turned out that many of these plastics not only replaced, but because of superiority for special uses, have made the original materials obsolete. This is an example of development and research which will have its parallel for many other materials as well, and should give impetus and encouragement to materials research.

A primary concern of product manufacturers today is that of obtaining materials of uniform quality from one ordered lot to all the subsequent ones. This is an absolute necessity for even and good quality production, and it is a point of such vital importance that it must be offered the maximum attention.

Many industrial undertakings especially in the public sector, are of such magnitude that research and development must be an integrated part in the undertaking. For private manufacturers, particularly on a smaller scale,

the research and development must be left to national laboratories. The importance of that any industrial undertaking must avail itself of all possible guidance aud consultation obtainable cannot be emphasized enough. Such aid must not only be limited to choice of materials and control of materials and products, but must also deal with proper designs and functional properties of the products as well as further developments.

It is often heard of, and it definitely makes sense, that research in India must develop materials from locally available sources which may be used as substitutes for presently imported ones. This may be considered a sound approach, but an even sounder, I believe, is that of developing indigenous materials which have better preperties than the imported ones when the special conditions in India regarding climate, maintenance, production facilities, labour etc. have been considered. This calls for ingenuity of high calibre, but mainly it requires cooperation and coordination of the present research facilities.

Once an idea is born, the stage of development follows. This requires keen devotion, patience and endurance, and the research engineer is confronted with a real and challenging test of his qualities.

Testing and control

If the materials have been developed and are available and the production has started, the economy of day to day operations becomes the most important factor. It is at this stage that testing and control must be stressed, and the economic advantages of such conttol must be understood.

To introduce testing in a production line is most often thought of as a time consuming factor slowing up production rather than a necessary and economically sound way of keeping the machinery going with minimum wear and maintenance operations and the turning out of quality products. It happens again and again in industry that materials which would have been deemed unsnitable through proper testing and inspection, will undergo costly machining before the flaws are discovered. This is wasteful in many respects the time and cost of labour, the wear and tear of tools and machines, and the upsetting of production schedules will influence the price of production to such an extent that it completely ruins the competitive position of the product.

Control of materials may conveniently be carried out at the time the material passes from one owner to the next. One will discover that the economical responsibility of the supplier in relation to the purchaser is limited to the cost of the goods handed over. The purchaser is thus covered is so far as inferior or defective goods are concerned, but cannot claim anything for damages caused by such goods. It is natural that it is the purchaser who must demand control of the materials to ensure good and even quality and thereby protect his economical investments. In order to ascertain a reliable and objective control, it is natural that the control is carried out by a third party, an objective testing or research institution.

In the case of metallic materials it is natural to test :

(i) The ore, coke, and other constituents before these materials are handled at the steel plant.

(ii) The blooms, steel foundry sand, and other constituents before these are handled at the foundry.

(iii) Bars, plates, forgings, and crude castings before these go to the workshops.

(iv) Foundry products, machinery and construction before they are put into operation.

When ordering materials for certain products it is very essential that the specifications for such materials incorporate requirements regarding essential machining properties. A manufacturing process involving forming, shaping or other handling of materials will necessitate requirements regarding such technological properties. Tests to control the success of any such operation will prove economical in most instances. It is quite possible that such control can reveal flaws or imperfections which make the material unsuitable for further processing. A typical example of such control is that of welds. It is absolutely essential that such control is that of welds. It is absolutelv essential that such control is carried out at an early stage so as to reveal if other types of materials or connections must be use. It is also possible that such control will indicate the necessary alterations of the process itself. It is a fact confirmed by experience that any control or testing carried out on the shop floor is much less costly than any later control carried out when the product or construction has been taken into use.

Large research organizations usually do not carry out testing and control of industrial materials and products. As a matter of fact, they often shy at such projects which they believe are below their scientific level. This view is often very incorrect, because such practical problems will reveal the actual needs and difficulties encountered in every day industrial life, and the solutions to such problems will immediately benefit the industry and thereby economic and industrial development.

The industrial undertakings in all developed countries have long since realized the importance of their daily contact with research organizations which can give them advice when needed. The cost of such contact is small indeed in comparison to the gains that such relations may yield.

Maintenance

In the industrially developed world, the problem of maintenance of materials, products and production machinery is of vital importance and grave economical magnitude. In a developing country like India, this problem may even have greater significance due to a limited supply of both materials and products. I do not believe that exact figures are available, but yearly expenditure due to corrosion of materials and products in India alone must be hundreds of crores of rupees. The problem of proper maintenance thus becomes of very major importance in any industrial undertaking.

Applied research cannot care for all the problems of daily maintenance in industry, but every one engaged in such research must be fully aware of the problem and take every precaution possible to minimize the impact of destructive factors calling for large maintenance costs.

One often associates quality with longevity of a product, and this is definitely often a good comparison. In such a case longevity is not arrived at by constant and expensive maintenance, but rather by high quality materials with appropriate properties, the correct treatment of such materials and a scientifically correct protection by metallic coating or similar if required.

The problem of material specifications thus must consider the important aspect of maintenance of the product such materials are to be used for. In this regard, the environmental factors such as certain atmospherical contaminations, humidity, temperature conditions etc. must also be paid attention to. In problems of finding replacement materials for imported ones, the question of possible combinations must be remembered. The materials in contact with each other, or even only close to each other must be of the same electropotential. The problem of cathodic protection may have to be considered. One material may have a long life with fairly rough and unprotected surface, whereas another material may require a high polish and/or a protective coating.

The problems associated with competitive industrial products purely from the point of view related to maintenance are very vast indeed, and the economic importance is vital to a developing country in particular.

In stating the essential aspects of materials and product control, the choice of materials and processes and the impact these factors have in achieving not only industrial independence, but also industrial sophistication, I have merely tried to stress the importance of applied research as a vital tool to cope with these problems. The magnitude and complexity of the problems are most often considerably beyond the understanding of the average engineer, and only pooled resources will successfully tackle them.

As industrialization further progresses it will only become more and more evident that a large responsibility for providing the expected results lies with our institutions for applied research.

Research and Industry

S. K. DUTTA
Burn & Co. Ltd
Howrah

The real defensive and sustaining strength of any country lies in its wide industrial base and in this no less than skilled workers, good management and realistic planning, research plays a vital part. Research alone can meet and change the needs and moods of industry. Research does not mean mere intellectual activity. 'Research' should be encouraged, planned and worked as 'Industry' itself. As in industry, in research also, my formula for success, in the context of today's needs, is DP_3M_5. D is the determination with which we should launch upon a campaign for research. Three P's stand for Patriotism, Planning and Profit. The motive must be patriotic, the feasibility is to be planned and the work undertaken should produce dividends. Without dividends quickly growing from it, research becomes infructuous luxury which we cannot afford today in this country. Then, of course, there are the five M's for Money, Machines, Materials, Men and Management. For a healthy and beneficial growth of industrial research each of these factors has to play its part in due proportions and in complete harmony.

Industrial research is not an end in itself. Its usefulness depends on the speed and readiness with which the industries would be able to put its findings to practical use and to produce saleable products and equipment embodying new technical developments and advances. Industrial research today in this country becomes vitally necessary in the context of import substitution which is so crucial to India's economy. Generally speaking, the success achieved so far in the realm of import substitution has not been large but this has been due to lack of industrial research. If our country has to make rapid industrial advancement, high orders of innovations would be required. The speed of innovation is also an important factor which can be derived only by intensive research work. A major preoccupation in industry should, therefore, be the early organization of systematic research into the problems of industry.

It should be admitted that the flow of research information to industry today is slow, irregular and inefficient. This has resulted in saddling our undertakings with obsolete technologies in many instances, which carry the necessary punishment in the shape of higher production costs and lesser production quantum. These, if prolonged, can plague our industry for decades. In an underdeveloped economy it can indeed be disastrous. No doubt there is a woeful shortage of risk capital in the country and perhaps not much can be done about increasing its supply. If planning, direction and exploitation of research work are put in competent hands, the half-baked character of some pieces of research can be avoided. The other way to reduce the drain on risk capital is to make research work, as much as possible, and it is possible to a great extent, a continuous and integral

part of industrial production. Attempts should be made to provide and improve facilities for research thinking in course of day-to-day manufacturing activities in the works. In this way much can be achieved. On the other hand if we are thinking of properly set up research laboratories, precaution should be taken to avoid the nurturing of any research work whose results would be premature for the current industrial or market conditions. Historical instances are not rare about long delays between achievement and application. The gap between the discovery and use of telephone was 56 years (1820–1876), it was 35 years (1867–1902) for radio and 14 years (1922–1936) for television. Let us not waste our capital and efforts in directing any research work for things like telephone, radio or television. Then there is the vital need for avoiding any duplication of efforts and this can be achieved by quick communication and dissemination of all research activities in the country—whether in the laboratories or on the shop floors. Perhaps the Council of Scientific & Industrial Research will undertake this job more comprehensively. Engineering societies like the Institution of Engineers (India) or the Indian Engineering Association may as well give many opportunities to their professional members to keep abreast of the new techniques and methods through journals meetings, expositions and the like.

The place where day-to-day research work that I am envisaging in the existing circumstances, can be carried out is inside the industrial undertakings themselves, in industrial cooperative research associations or in full-fledged laboratories. The order in which I mention these three places is rather significant. Our requirement is not so much of research work of fundamental nature as of the same for small and large improvements and innovations in production, process and usage, and therefore the shop floors and the drawing offices can provide adequate facilities for achieving innovations, if we hesitate to use the word research, cheaply and quickly, which have direct application and use of immense benefit. The Burn and Co. Ltd. Howrah with which I am associated, is one of the earliest engineering concerns in the country. Nearly completing its second century this Company has been associated with many pioneering and development work. In this pioneering work our Company has maintained its own quota of research activities. Ours is an integrated industrial unit served by design and drawing offices as well as physical and chemical laboratories chiefly rendering service to manufacturing activities and quality control. Yet, unsophisticated as these are, we have been able to achieve some striking results after due efforts through analyses and experiments by our own assistants.

It would not be out of place to mention, only a few of these results. About 10 years ago rivet snaps were made of imported steel and these could be replaced by indigenous high carbon alloy steel after extensive experimentation. Considerable improvement has been achieved in pressing work by innovating what can be described as collapsible punching die. Another example is the replacement of non-ferrous bearing shells in rolling stock by spheroidal graphite iron castings which eliminates pilfering. The major disadvantage of the use of CO_2 in moulding is that under the heat of the molten metal the sand sets rock-hard. Experiments all over the world had been carried out to find expensive breakdown compound. The solution at Howrah has been found with the use of a sand mix of sodium silicate and dextrine without any imported breakdown compound. We have also succeeded in eliminating the use of anything in CO_2 cores by adopting hollow cores. Bonding clays such as full bond from the UK or Wyoming

bentonite from the USA, have been successfully substituted by Indian bentonite. Steel castings as heavy as locomotive bolsters weighing about 1·5T. have been made by green sand process with Indian Bentonite. In the Iron Foundry the common expansion scabbing problem connected with green sand moulding has been overcome by introducing a judicious percentage of sawdust along with redesigned running arrangements. In the field of welding also the most noteworthy achievement was the replacement of imported automatic welding wire by indigenous wire rolled by the Indian Steel Wire Products Ltd, through our initiative and on the basis of specifications supplied by us. Incidentally, import of this wire has since been completely banned. The process of fire cracker welding unknown even in the UK, was independently developed in our works resulting in higher productivity and lower costs. Thus, it is not a futile statement if I say that research like charity, begins at home.

The other places where research can be carried out are cooperative research associations to be set up by the industrial concerns as well as research laboratories. Nearly fifty years ago the UK was first to conceive industrial research through cooperative associations. Cooperative research for industries as a whole is at present undertaken is a part of national policy in twelve European countries such as Austria, Belgium, Denmark, France, Germany, Norway, Sweden, the Netherlands, Italy, Spain, Switzerland and the UK. In these twelve countries there are nearly 250 cooperative research organizations. In this country the idea of encouraging user's participation in research through research associations is relatively of recent origin. The first association of the kind was established in 1947 dealing with the cotton textile industry. A few more associatlons are in the formation stage for the automobile, jute, radio and electronics industries. The Reviewing Committee (1964) under the chairmanship of Sir A. Ramaswami Mudaliar commended the policy adopted by the CSIR in respect of research associations established for the engineering industry. May I suggest that although the pattern of these cooperative research associations, their mode of operation, financial support by the government and the contribution by the member companies may vary from one industry to another, the one factor must be common to ensure that 11 of these undertake research for the benefit of all their members irrespective of their sizes, the basic idea being that in developing economy, it is desirable for even the competing firms in any industry to provide facilities and direction of research to be undertaken, in the first instance, for the benefit of the industry as a whole. If the circumstances and capacity permit, there should be no objection, however, to taking up 'secret' research work for individual sponsors in addition to joint research for the industry as a whole.

The third place for industrial research work is our national laboratories which are indeed useful but these cost money and would be of little use if the communication between the laboratories and the industries is not streamlined. The existing potentiality is tremendously high and I may be permitted to mention that we need not go in for more of these until we have fully utilized the existing ones. Many of you may know that according to a report, out of 334 processes developed by our national laboratories, our industry could use only 61 processes. In fact much of the research work till lately undertaken by the laboratories was not of immediate use to industry. The Third Reviewing Committee which investigated the work of the national laboratories, unanimously agreed that Indian industries were not without reason, unenthusiastic about the work done in the laboratories. Unless the techniques developed indigenously are beneficial in respect of

quality and cost of production, the apathy of our industrialists will continue.

The place alone is not enough for research. We have to build up a substantial garrison of competent men to undertake the work whether on the shop floors, in the cooperative research associations or in the national laboratories. In this regard, paucity of funds should not be an acceptable excuse even in the present emergency situation. It would be pertinent to mention that during the Second World War, the emergency situation in England was many times worse than ours, yet they trebled the peace time figure. The problem of education is both a form of consumption and a kind of investment. Like food it is something we use or consume; yet, like a dam or canal, it is something in which we invest to produce more in the future. Talking of research workers alone for the present about 10 to 15 per cent of the technical graduates have aptitude for higher studies and research work. For them, the doors of the post-graduate university courses, and national laboratories should be kept open. In addition to providing some of the best men for the universities and the national laboratories, two or three national institutions should be established on the lines of the French Ecole Polytechnique or the French Ecole Nationale d'Administration where tremendous prestige attracts the most gifted and only the most gifted can succeed in the fierce competition for entry. Through a central agency, a vigorous search for the best talent should be made in our schools and colleges and then special facilities provided for intensive training for the most promising so that they may enter stiff competitive examinations. As a result of such examinations, only the ablest, not exceeding a few hundreds at the outset, should be trained for at least three years in these two or three national institutions which should be uninhibited by traditional concepts and course of study and be free to innovate and experiment. A beginning towards this direction has been made in our country by the Sir Jagadish Bose National Science Talent Search Contest.

The maturity in industry can be achieved through organizing proper research work for which the task before us is tremendous and I summarize this task under five heads:

(i) Develop public opinion in favour of undertaking industrial research is a business-like manner.

(ii) Communicate and disseminate all research results freely to all industrial units on one hand and on the other collect their problems.

(iii) Encourage company research through discussions and seminars.

(iv) Organize cooperative research associations on a realistic basis with the help of the existing national laboratories and keeping in constant touch with industry.

(v) Develop research workers.

Translation of Laboratory Research to Commercial Production through Development Work

K. MANIVANNAN
Shri Ram Institute for Industrial Research
Delhi

Industrial research includes both the small scale (laboratory) research and development research. Laboratory (small scale) research is defined as "the systematic intensive study directed towards fuller scientific knowledge of the subject studied; development, on the other hand, is defined as the systematic use of scientific knowledge (gained through research) directed towards the production of useful materials, devices, systems, methods including design and building of prototypes and processes". Development is concerned more with exploiting knowledge than with adding to it. The development work includes the transference of new processes from the laboratory work to large scale production through the pilot plant study which belongs to the field of process and product development and the study of behaviour of existing full sized plant unit by means of suitable models, which belong to the sphere of the process and plant study.

The qualities and training needed for the development staff are quite different from those needed for doing (small scale) research work and it would be preferable to have two different groups of persons to do the small scale research and development work. This type of grouping will give opportunities for the staff to specialize in their specific branches and this will give more productivity per man. It would be also advantageous for the whole small scale research groups/divisions, for this group will think about their development needs and build the general development facilities and it would avoid the duplication of efforts and the facilities for the same type of work, thus avoiding the wastage of materials and human efforts.

One important criterion for the successful working of the development division in an industrial research laboratory is a proper organization (as in any other field of activity), a system of organization which will be conducive to cooperation between the research and development groups and which will also induce both the groups to put in their best. One such is the functional organization with the provision for problem team grouping.

In the functional type of organization, the personnel are grouped according to the end product/process such as product research, process research, process design, instruments analysis, general services, development etc. This functional type of organization is inherently conducive to create cooperation among staff. The problem team grouping, means that the persons are grouped/selected from the different divisions/sections on the basis of the requirements visualized in solving specific problems. The

functional type of organization with provision for problem team grouping will provide facilities for specializing in one field and at the same time make it possible for the persons specialized in specific fields to use their specialized knowledge for the successful completion of the project in hand. This type of cooperation is necessary between the small scale research group and the development for successfully transferring the small scale research work to large scale production. One important feature which will improve this cooperation is to give due credit to all the persons who associate with the successful completion of the project; as a matter of fact one should be a little lenient in giving the credits to the persons rather than be strict over the same, this would increase the cooperation between the persons and groups of persons. Another point which will improve the cooperation is the attitude of the head of the organization, who should create more and more opportunities for the people from the different divisions to work together and also appreciate the cooperative efforts openly.

It would also be necessary to associate the primary inventor of the process/plant in the laboratory with the project in a very close manner, so that his enthusiasm and his long continued interest and association with the project will help the project in a substantial way.

Another important criterion is to provide adequate resources to make provision for the essential needs in terms of personnel, equipment, and space to locate equipment and for the personnel to work, and above all this, enough money should be provided to do the development work of specific projects. Many a time, it is not well appreciated that the finance needed for development work is of much higher order than that needed for doing laboratory research work.

The experience of the Shri Ram Institute for Industrial Research during the last fifteen years in translating the laboratory work to commercial/industrial scale operation has shown that this high order of expense for this scaling up work is inescapable. This point has often been emphasized by Dr V. B. Chipalkatti, Director, Shri Ram Institute. This point is elaborated in Figs. 1 and 2. It can be seen that the development cost (pilot plant and model work) varies from 5 to 20 times of the laboratory work (depending upon the type of the projects) and for successful implementation of the project many other research services such as, process design, product design, market research etc. are needed. So it is necessary to appreciate the needs of the development division and

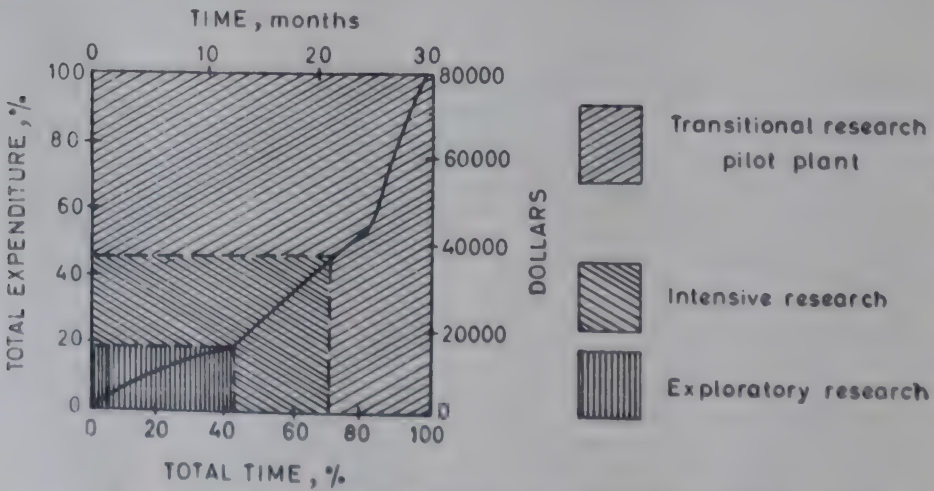

Fig. 1—Expenditure and time for a complete research project

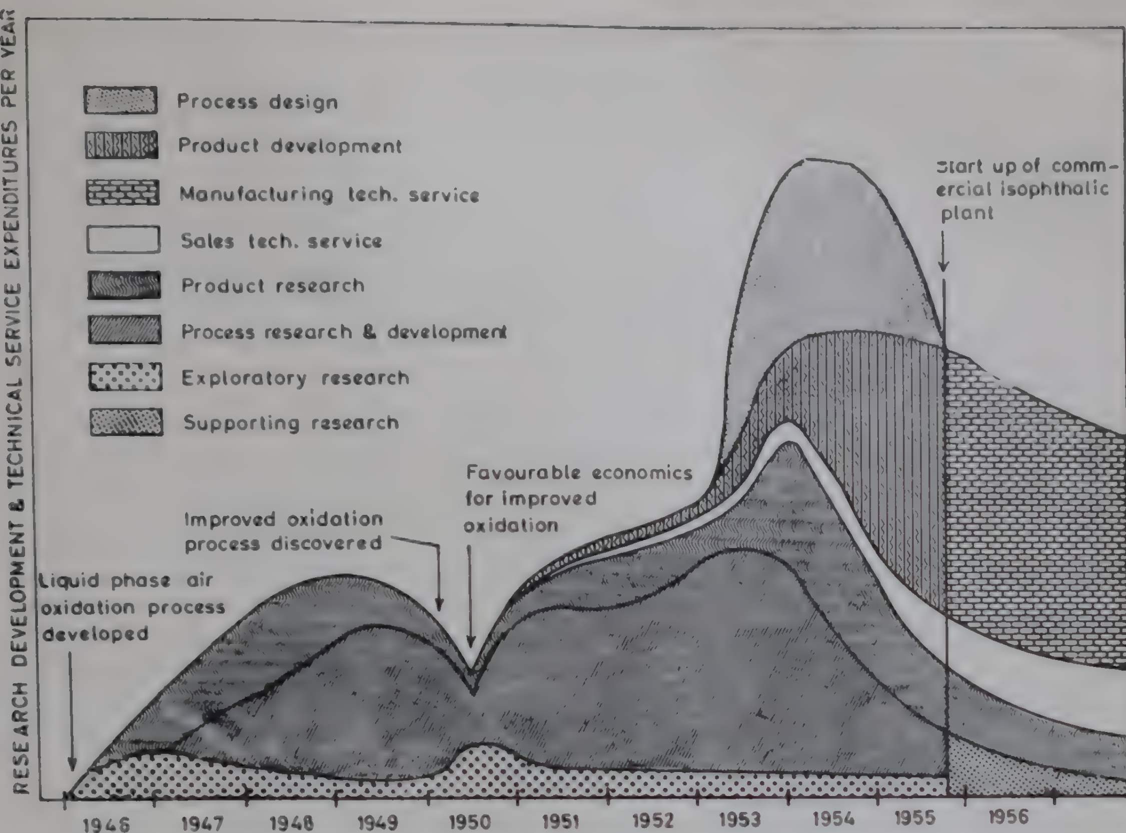

FIG. 2—RESEARCH FUNCTIONS FROM INCEPTION TO COMMERCIAL FRUITION (THE ISOPHTHALIC PROJECT)

provide necessary resources for the successful implementation of the processing and useful projects worked out in the laboratory, which otherwise cannot see the limelight of production. Otherwise the functioning of the division will be impaired.

One may argue whether it is necessary to do this costly and time consuming pilot plant experiments in all cases. As a matter of fact, attempts are afoot to avoid the pilot plant work in the advanced countries, where there is keen competition between different industries and also between different countries. One striking example is the isotope separation associated with Manhattan Project. And further, the development or scaling up of work cannot be left off in all cases even in advanced countries for this study, apart from providing the process and design data, also makes available the trickle production of the product with a view to finding out the consumer acceptability of the product and the market survey/demand, the scaling down studies of process/plant (especially plants) cannot be done in commercial units. Then the development work cannot altogether be omitted.

Attempts to jump over the pilot plant/model work are not possible in the developing countries like India, where there is neither the tradition nor the experience and expertise in using the laboratory research work for making large scale production, where there is no 'unlimited money' to provide high factors of safety in designing the large scale equipment and where there is no experienced staff to face the massive teething troubles that would arise in the large scale production when done without going through the scaling up in stages. Thus the development work becomes an important and an essential link in the chain of process/product development and study.

As this link is weak (and nonexistent in some places) due to many reasons, e.g. (i) not enough resources are available at the disposal of this

development division and (ii) there is no good cooperation among the staff within this division and between the small scale research and development division due to faulty system of organization or not giving proper incentive for cooperation etc.; many a useful and promising (potential) projects do not see the light of development and industry. When the rapid economic development is being attempted in the developing countries like India, the work of researchers will come to limelight and make an impact on the society (which is very necessary in a democratic set up) only when they are utilized by the industry for starting the production of new items for increasing the production of the existing items or producing the existing items more economically.

Due to acute foreign exchange problems, there are drastic cuts on many imported items which are essential for running of many industries. So attempts will be made by researchers in the laboratory to make the items that were imported, or at least to make substitutes for the same. These products (and processes) developed in the laboratory have to be scaled up.

No foreign country, however philanthropic it may be, will help India in a big way to build the development work or imparting this know-how, so this school of development has to be built here and experience is to be gained. Sooner it is started better it will be for the nation and sooner it will be for India to stand on her own.

During the development work which is an important and essential link in the process/product development which is intermediate between the laboratory research and commercial production, and also in attempting to oust this expensive and time consuming scaling up work in stages, in this world of keen competition attempts are to reduce the 'Wait Period' between the time of getting an idea and the time of commercial utilization of the same, this reduction is being brought about by providing adequate resources to take care of the huge needs of the development work, in terms of finances, technical manpower, and epuipment, by utilizing the experience gained in earlier work as the foundation for future work by using research sophistication and above all by providing an organization which is most conducive and which encourages cooperation among the different groups of persons in the same organization.

From the above, it can be seen that the Development Division is a must in any laboratory/organization doing industrial research and for its successful working a good organization (functional type with provision for problem team grouping) conducive to cooperation among the different personnel in the different divisions and especially those working in small scale research and development division and a head of the organization who believes that the cooperation is the keynote of success, association of the primary inventor with the project up to the stage of commercial production and adequate resources at the disposal of the development division are required. Cooperation between small scale research and development divisions on one hand and the research institutions and industries on the other will go a long way in the reduction of the current 'lead-time' from the conception of the idea to the successful commercial production.

This can be concluded (similar to Presgrave's remarks on the time study) that the true aim of development work, like the true aim of medicine, is to eliminate itself. If in working towards this aim, the development workers make themselves indispensable that is a happy paradox helping to humanize professionalism and to soften the austerities of the technique.

Financial Control of Industrial Research

J. DUBASHI
Economic & Scientific Research Foundation
New Delhi

Profitability is the normal yardstick for measuring the efficiency of various departments in a company. Most directors know how to use this criterion for such departments as production, sales and marketing. But many are baffled when they try to apply it to the research department. They realize they are investing in new knowledge that could be vital to their prosperity but because the processes of science are esoteric they feel they must take the efficiency of research on trust.

This is unsatisfactory because research is extremely expensive and should be very carefully controlled. It has been estimated[1] that India spends about Rs 600 million a year on research and development which, although less than 1 per cent of the country's national income, is indeed a substantial sum. In advanced countries, the expenditure on R & D—this totals nearly £ 800 million a year of which the Government accounts for about £ 500 million and industry the rest. There is no doubt (according to a source) that "a great deal of this vast sum is wasted". This is a misfortune not only for the firms that are paying the bills but also for the nation. The Economic & Scientific Research Foundation has estimated[2] that "the contribution of national laboratories in the way of technical know-how and other services touches a bare *one eight of one per cent* of the entire industrial production in the country", implying thereby that the financial returns have been poor. It is the purpose of this paper to discuss the principles of financial control of industrial research.

Industrial research consists of:

(i) Fundamental scientific investigations designed to discover new knowledge.

(ii) Development of new processes, new products or new equipment based on existing knowledge.

(iii) Continuous improvement of existing processes, products or equipment.

These divisions are not inflexible. Inevitable there is some overlap and intermingling among the three areas. Nevertheless, the classification is convenient.

Fundamental research

Any money spent by industry in carrying out fundamental research in its own laboratories might as well be poured down the drain. To justify

this statement it is necessary to consider some of the characteristics of this type of research.

First, by its nature it must be completely unplanned and free from directive control. It is slow, expensive and unpredictable. The vast majority of it will be useless, and even the small percentage of useful knowledge will almost always be usable only over a long period of time during which it will be almost impossible to keep exclusive. Once larger companies in the west prided themselves on carrying out fundamental research, and set up expensive laboratories to do it. The more discerning have now ceased these unprofitable operations and use alternative means of keeping in close contact with the frontiers of knowledge—which is the real object of research.

The best place for carrying out fundamental research is universities. Therefore, a firm should seek to secure close liaison with a few carefully chosen university scientists who are working in the fields in which they are interested. This can be done by appointing university scientists as consultants, by temporary secondment of industrial staff to universities, and by temporary employment of university staff in industry. In all cases the desired objective will be more readily obtained by the firm setting up an efficient research liaison and information section, and there is the only permanent fundamental research activity in which any industrial organization should indulge.

It is not known how far this is being attempted in India for the general lack of mobility of staff between industry and universities must be a restraining factor.

Exploiting innovation

Applied research, or the exploitation of new knowledge, should be the major activity of an industrial research laboratory. However, the rules for carrying it out successfully are quite different from those for fundamental research and failure to appreciate this is all too common. Complete freedom, which is essential for the full flowering of 'pure' research, can very easily become merely an excuse to explore all the interesting side-alleys, instead of following the main road to the planned objective. Detailed planning and continuous control of applied research is essential. No new development should be started unless the following particulars are known and assessed.

The objective—A clearly defined technical definition of the new process or product which it is planned to achieve.

The value of the objective—Assuming a successful result, how worthwhile is it to the firm concerned? A number of factors need to be considered: the market potential for a new product, the likely profitability, the capacity of the firm to manufacture, the activities of competitive firms, etc.

The cost of development—Both time and money must be included, as well as the availability of suitable men and equipment.

On something like the above lines—elaborated to include all the factors relevant to a particular case—a kind of balance sheet can be made out for any proposed new development. The only unknown factor is the probability of a successful result within a given budget and time-scale, and here reliance must necessarily be placed on the judgment of a research director.

Anybody in a firm should be allowed to suggest a new research project. But no suggestion should be considered without at least a brief analysis on the above lines. In practice, the most prolific sources of suggestions should be the marketing department, the research liaison section, and the research staff themselves.

If the preliminary analysis is favourable, stage 1 of the project should be carried out. This should be strictly limited to preparing a report from the research liaison section on all the relevant scientific knowledge, a report from the laboratory on the feasibility and cost of the whole project, and a report from the marketing and production departments on the value of the objective. Only after all these have been carefully considered should a decision be made. As a result many projects may be killed or postponed at the end of stage 1—before any major expense has been incurred. The survivors will be all the more worth pursuing with enthusiasm.

Once a research project has got over this first hurdle, the most important commodity is time, and almost everything else must be subordinated to this. As an example, a buyer who saves Rs 1000 at the cost of a week's delay in delivery may be doing his firm a gross disservice. Similarly, it may be unwise not to buy expensive equipment if by so doing the time taken on the research project is shortened. A corollary of this is that research time must be meticulously accounted for and progress reviewed frequently and regularly. If the project does not proceed as originally planned and this will happen more often that not—then the plan must be reviewed. If this indicates that the project should be dropped there should be no hesitation in doing so. In research, "more money is wasted in flogging dead horses than in almost any other single way".

When a research project has reached a successful conclusion it is most important that the laboratory staff clearly understand that their responsibilities are by no means ended. It is just at this point that the greatest weakness in the process of innovation lies. It is common practice for the research staff to write a polished 'Final Report'—often taking several months of expansive time to do so. This is then handed on to 'Production', and the research people proceed to wash their hands of the whole matter. 'Production', of course, simply reinvestigate the whole thing almost *ab initio* from their own point of view. The amount of time unnecessarily wasted, and the number of projects which fall by the wayside at this stage, is tragic. The point is brought home forcefully when some other firm successfully brings out first a new product based on exactly the same initial grain of new knowledge that was originally available to all.

The cure for this weakness is close liaison with other departments during the course of the research work, and after it is completed. The first can be achieved if all departments take an active part in the frequent regular reviews of current research. The second is often best achieved by transferring some of the research staff to the production or even marketing departments either temporarily or permanently. Alternatively, it may be appropriate to start production in the research laboratory itself. Whatever the solution in any particular case, the aim should be to save time and to avoid abrupt transfer of responsibilities for a new project.

Continuous improvements

Many industrial research laboratories do a great deal of 'routine testing' and quality control of raw materials and finished products. This is really

no part of 'Research', even though it may require the use of advanced and complex equipment. It should be organizationally dissociated from the research function. A rather more borderline case is the continuous improvement of existing products and processes. This may often involve large numbers of 'routine measurements'. Managements should not be too dogmatic about how to treat this function organizationally. In some cases it may be obvious that the production department should carry out its own continuous improvements; in others it may be virtually impossible to decide whether one is dealing with a simple improvement or a radically new project. In any case, the principles of initial justification and continuous review and control remain the same as already described.

Illustration

In order to illustrate in a practical way how a company might control its research budget in order to obtain the utmost value for each rupee spent, let us set out some figures. Assume the firm has 1,000 employees and a turnover of Rs 30 million. The total expenditure on R & D should be about 1 per cent of turnover to start with, i.e. Rs 4,50,000. The research staff should be about 2 per cent of total personnel, i.e. about 20.

		Rs
1	Research Director	2,500
2	Senior Research Staff (at Rs 1500)	3,000
2	Research Staff (at Rs 1200)	2,400
3	Junior Research Staff (at Rs 900)	2,700
6	Technicians (at Rs 500)	3,000
3	Trainees (at Rs 300)	900
4	Clerical Staff (at Rs 250)	1,000
		15,500 per month
		or Rs 200,000 per annum

These salaries are high but they are needed to get the best staff for a model research establishment. The annual budget will be as follows:

		Rs
1.	Salaries and wages	200,000
2.	Other personnel expenses	30,000
3.	Materials and apparatus (written off immediately)	100,000
4.	Library & information services	20,000
5.	General overheads (services, travel, maintenance etc.)	60,000
6.	Depreciation on fixed assets etc.	40,000
		450,000

The amount of work which might be done with a budget of this size can be envisaged as under:

		Rs
1.	2 Major projects (development of new projects/processes)	180,000
2.	4 Minor projects (improvement of existing products)	120,000

3.	6 Support projects (i.e. cost reduction investigations etc.)	100,000
4.	General information & liaison work	50,000

Once it is realized that research is just as susceptible to analysis and control as any other function, the management may not shy away from it. Industrial scientists should make it a part of their duty to dispel the myths and mystery about R & D and educate management on its costing and control. It should therefore be possible for a business-minded research team to point out the direct and indirect savings flowing from its research findings and to persuade the management to set off a part of these savings against the cost of research. Unless a particular process or technique has reached the limit of its technology, or the research team in question is not up to the mark, or there is a lack of rapport between the management and its research team, it should be possible in the long term to balance the two sides of the 'research and technology account'. An Indian firm has described its own method which, incidentally, throws considerable light on the organization and control of research in industry:

"We are a steel rolling firm and also have an expanding foundry business. Our turnover last year (1963-64) was nearly Rs 5 crores. The rapid expansion in business and the diversification of product range placed such a tremendous strain on our regular production and development staff that it was virtually impossible for them to pay more than routine attention to the task of effecting technical improvements in processes and machinery. We, therefore, asked a consultant to help us out on an ad hoc basis. The consultant was professionally better qualified than any of our staff and was also far more knowledgeable about new processes and techniques. It took him some time to get the hand of our business but he was able within a few months to inspire confidence in his technical ability to deliver the goods and also guide us in the actual design and engineering of some of the new equipment suggested by him.

"As the work was growing, we decided to have a small research unit of our own and invited the consultant to take charge of it. The consultant was unwilling, as he was a research man in his own right and was also associated with a basic research programme of the local engineering college. He was reluctant to give up his 'basic research' connections and take up whole time applied work, although he would thereby improve his income by nearly 60 per cent. Finally he accepted the offer on condition that he would be permitted to devote a portion of his time and the company's resources to his own work which would often have little direct bearing on the company's business.

"It was a very small unit to start with, consisting of the scientist himself and two junior assistants. When work increased and the question of expansion was brought up, it was necessary to devise a suitable formula. It was agreed that 50 per cent of the notional reduction in manufacturing cost effected as a result of the improvement suggested or carried out by the research unit would be credited to the account of the unit for a period of five years. For instance: if we produce 2,000 tons of a particular product per year and the research unit is able to trim off Rs 50 per ton in the manufacturing cost, we could write a credit of Rs 1,00,000 into the research account. This would then be set off against the cost of maintaining the unit.

"This system has been in operation for only a few months and seems to be working satisfactorily. The research unit hopes to be paying for itself in about six years' time. We are spending about Rs 1 lakh per year on the unit which means that in about six years' time it will have accumulated sufficient credit to wipe out the sum of Rs 6–8 lakhs which will have been spent on it during the period".

REFERENCES

1. Research, Technology & Industry, Economic & Scientific Research Foundation, New Delhi, 1965, 15.
2. *Ibid*, 30.

Import Substitution and Conservation of Scarce Materials—Scope for Research and Standardization

GURCHARAN SINGH
Indian Standards Institution
New Delhi

The case for the conservation of imported and scarce materials, equipment, spares and components and their substitution with products available indigenously has a logic of its own independent of the urgencies imposed by the present situation. The emergency, the foreign exchange shortage and the somewhat uncertain external aid prospects have only served to give a new dimension to the problem which has been with us all these years. While some of the shortages are genuine, there are others which can be easily overcome if the requirements of the different sectors of the industry are organized and coordinated on a systematic basis. A good deal can be achieved if the requirements are evaluated in terms of precise details of quantities, sizes and properties and a conscious effort is made to find or develop suitable alternatives from indigenous resources. In USSR, for example, the demand for nickel and tungsten has been kept low by replacement with more readily available manganese, chromium and vanadium particularly for stainless steel, tank armour and artillery barrel liners.

In the quest for rapid industrialization, the Indian entrepreneurs during the early formative years entered into collaboration arrangements with a number of overseas firms belonging to different foreign countries. While these collaborations were useful initially for supplementing the indigenous capital resources and know-how, they also brought in their wake the problems of multiplicity of standards for raw materials, spare parts, design practices and even system of measurements. This has forced the Indian industry into the unenviable position where it is required simultaneously to adhere to the national standards not only of India but also of countries like USA, UK, Germany and USSR. The consequent fragmentation of the demand offers little incentive to the ancillary units for taking up production in view of the uneconomic quantities involved.

Then there is the question of sheer inertia because of which the primary tendency is to meet the requirements through tailor-made imports and ignore the possibilities of using locally available materials to the best advantage. This entails double wastage. Not only does it lead to the expenditure of precious foreign exchange on avoidable imports but also that the available resources remain unexploited. The import of technical know-how also stifles technological daring and comes in the way of the utilization of the domestic efforts in research.

Role of science and technology

In the struggle for self-reliance and self-sufficiency, science and technology have their own important roles to play. It is through laboratories and their proving grounds—the pilot plants—that the validity can be tested of the new materials, new designs and new techniques materials. For a developing country, the enlargement of its technological base is a foremost necessity. Efforts have, therefore, to be concentrated on the development of applied research facilities in the country as well as for fostering a closer relationship between research and industry. The compulsion to depend entirely on our own resources and to do away with imports will prove beneficial in the long run in the sense that it would encourage ingenuity and innovations.

After independence, the country has taken major strides in the direction of power generation, irrigation, steel production, oil exploration and refining, machine building and industrial growth. A lot, however, remains to be done with regard to the problems of components etc., which are the major areas of deficiencies. True, there is a limit to what can be done with regard to the replacement of basic materials, but much can be achieved regarding items like spare parts of imported equipment, the annual import figure for which is of the order of Rs 2000—3000 million. Substitution, it has to be understood, is a continuous process since competition, rising costs, and improvement of quality always load to newer designs, materials, processes and treatments. The native scientists and technologists have, therefore, an enterprising field before them for developing the internal productive resources of the country.

Efforts are also needed on the front of dissemination of the results and achievements of research so that they could filter down to the quarters needing them most. A number of examples are there where admirable schemes developed by our laboratories never saw or left the pilot plant stage. An efficiently organized publicity campaign can do a lot to persuade the local industrialists, manufacturers and other entrepreneurs to try out the nationally developed techniques and products.

Standardization and substitution

The importance of standardization and interchangeability in any programme for the replacement of imported stuffs and materials needs hardly any emphasis. A substitute, in order to be successful in its purpose, has to be a 'functional substitute', that is, without being an exact replica it should perform all the functions and services expected of the original. The substitute, being a compromise, has to be selected judiciously taking into account a multitude of factors. It is here that standardization and the platforms offered by the technical committees and sub-committees of the ISI can play a significant role in arriving at intelligent choices.

Standardization which in essence is nothing but the application of sound common sense to the everyday problems of manufacture can help to achieve a great deal of economy and give order to developments which may otherwise go astray. Standardization enables production to be rationally coordinated with consumption, new engineering techniques to be applied in industrial practice with less expenditure of labour and finance, and leads to achievements of higher rate of production, improvement of quality and perfection of trade facilities. The very process of the development of standards with consensus and overall agreement of all the interests concerned—manufacturers, consumers, traders, technologists, engineers,

scientists and material experts—ensures that all the related factors mattering to the production and serviceability of a product have been taken fully into consideration. It would thus be in the fitness of things that all the problems and proposal of substitution and conservation are brought for examination before the over 1500 technical forums—sectional committees, sub-committees and panels—established by ISI for formulation of standards in so many specific fields.

Ever since it was set up in 1947, ISI has been endeavouring for rationalization, simplification and variety reduction in Indian industry and trade. In the formulation of Indian standards, a good deal of attention is paid to the utilization of indigenous materials and resources as far as possible. In some of the fields, the efforts of ISI to impart order to the chaos created by diversity of specifications and practices has borne rich dividends. A few of these examples where standardization has helped to achieve significant savings in imports as well as conservation of materials in great demand are given below which may stimulate interest for similar achievement in other sectors of economy.

Building materials. India faces an acute shortage of essential building materials, like cement, steel, and timber, which is forcing attention on the review of the current civil engineering practices for making a more prudent use of the available resources. Shortage of portland cement has led to increased interest in the use of lime and pozzolanas like fly ash, surkhi, blast furnace slag, etc. Attempts to conserve materials have also been made through popularization of prefabrication and modular coordination of building components. Indian standards have already been developed to specify requirements for such materials and components meant for structural purposes.

ISI has also done a lot of work with regard to structural and other commercial timbers and a number of standards prescribe requirements as well as species of timbers for particular constructional purposes. The Indian Standard Classification of Commercial Timbers and their Zonal Distribution (IS: 399) is a monumental work prescribing properties and uses of species of timber available in the country. The standard is proving a great help in doing away with costlier timbers procured from long sources where locally available species can se ve the purpose equally well.

Some of the imported timbers like redwood for use in cooling towers and African and American cedar for manufacture of pencil slats have almost entirely been replaced by indigenous woods. Wooden separators for lead acid storage batteries which were imported until a few years ago are now being entirely manufactured in the country from the indigenous species of timbers. Standardization played a notable part in all these substitutions.

Structural steel. The problem of increased steel production and its conservation in use has been attracting attention since the beginning of the planned developments. Under its steel economy programme, ISI has formulated standards on various aspects of steel production and utilization starting from basic steel products, going to design, fabrication and erection of steel work, and finally covering the problems of maintenance and corrosion prevention. The Institution has also redesigned the structural steel sections with an eye on economy and efficiency.

A study conducted recently by the National Council of Applied Economic Research (NCAER) revealed that nearly 23 per cent of steel can be

saved if all the standards developed by ISI for steel economy were implemented fully. Today, under an order from the Government of India, all the structural steel produced by the primary producers and registered rerollers has to conform to Indian Standard and carry the guarantee of the ISI Certification Mark.

Alloy and special steels. The alloy and special steel industry provides an interesting example of how standardization and variety reduction taken up in advance could stimulate the local interest in production of these items. The manufacture of special steels in the country was hitherto considered not feasible as the demand was split over 1500 varieties. As far back as 1955, ISI undertook a survey of the available data with regard to the present and future requirements of various types of steels in terms of tonnage and specifications and where possible in terms of forms, shapes and sizes. This led to the formulation of the Indian Standard Schedules for Wrought Steels for General Engineering purposes (IS :1570-1961), in which the varieties of steels were brought down from 1500 to 156 considered sufficient to meet the requirements of the prevailing demand. In the preparation of this standard due consideration was also given to the availability of indigenous alloying elements and the necessity to conserve scarce materials like nickel and molybdenum. In a recent review of the standard taken up to meet the present situation the varieties have been reduced further to 60 only.

As a result, a beginning has just been made towards the establishment of a carbon, alloy and tool steel industry in the country. While a major alloy steel project is being commissioned by the Hindustan Steel Ltd, at Durgapur, the Mysore Iron and Steel Ltd, Bhadravati have taken up a phased programme for complete switch over to the production of alloy and special steels in due course.

Aluminium for copper. India imports about 90 per cent of its requirements of copper and even after taking into account the increased production the shortfall in requirements by 1970 would be of the order of 100,000 tons. Here aluminium, in which India is self-sufficient, can replace copper in many lines of production. Aluminium has a place in electrical technology by virtue of its own technical merits apart from the consideration to conserve copper and zinc. The importance attached to this valuable nonferrous metal is evidenced by its production target in the Fourth Plan which has been raised from 60,000 tonnes to 300,000 tonnes.

The ISI has been aware of this problem and in the formulation of Indian Standards conscious efforts have been made to specify aluminium where it could serve the purpose equally well compared to other metals in short supply. Today a number of specifications are available on aluminium conductors and cables, doors and windows, utensils, storage bins, dairy equipment, bolts and screws, drawn and extruded tubes, etc. There are also specifications to cover primary aluminium products like ingots, castings, bars, foil, notched bars and ingots, short strip and wire. It would be of interest to record that the Government of India for the past many years has banned the export of aluminium utensils which do not bear ISI Certification Mark.

Miscellaneous. There are of course a number of other fields and products where standardization has led to import substitution. For example, the specification for standard sand has led to the replacement of Leighton Buzzard sand imported from UK for testing of cement. The 'Indian Standard Specification for Certified Samples for Metallurgical Analysis' is

expected to initiate the production of these samples within the country itself. Such examples can be multiplied further but they would be enough for the present where the major interest is only to draw attention to the scope and possibility of standardization in this direction.

The present emergency has only served to underline the need for undertaking similar projects of even bigger magnitude in other sectors. The Union Ministry of Industry has already sounded ISI on the need for reviewing current specifications of materials and to take up revisions where possible to substitute or eliminate the use of scarce materials. To begin with, a review would be taken up of standards on subjects of copper and copper alloys; lead, zinc, tin, antimony and tin alloys; light metal alloys; steel castings and forgings and steel products; insulating materials; winding wires; link clips; steel conduits for electrical wiring; conductors and cables; cables for vehicles; conductors for overhead lines; paper insulated lead sheathed cables; PVC insulated power cables; rolled aluminium rods for electrical purposes and wrought aluminium wires for electrical purposes.

The development of a proper company standardization activity in the country would also help to impart added impetus to the movement for self-reliance and self sufficiency. For the past three years, ISI has been straining efforts to promote company standardization activity in the country through training programmes organized with the help of UN experts. The industrialists of the country would profit by participating in these programmes with increasing enthusiasm.

Conclusion

As the country marches ahead, increased reliance will have to be placed on the internal resources. In this context, the scientists and the standards engineers are called upon to bend efforts to develop these resources to win freedom from dependency on foreign imports. Standardization being a dynamic process, ISI continues to revise every few years the standards and specifications formulated by it to give cognizance to the new products and techniques developed indigenously. It is also incumbent upon the industrialists and manufacturers to make increasing use of the domestic efforts at research rather than look to foreign quarters for import of technical know-how.

A Perspective on Considerations for Research and Development Policies

B. M. CHAKRAVARTI
Electronics and Radar Development Establishment
Bangalore

> "Science and Technology were once the condiments of our civilization. More recently they have been regarded as vitamins, tiny quantities of which could prevent stunted growth and enable us to absorb our industrial nourishment. Now they must be reckoned as the very meat and potatoes of our economy."
>
> **—de Solla Price**

There could hardly be a truer statement than Prof. de Solla Price's identification of the value of science and technology in our present era, so aptly stated in the lines I have taken from his first Annual Lecture of the Science of Science Foundation. I believe, too, that this realization of the importance of Science and Technology, and consequently the pursuit of Research & Development, is not lacking in India, as is evident from the organization of this forum and more so from the Government's endeavour to stimulate scientific and technological activity by its Scientific Policy Resolution as far back as 1958.

It is obvious, however, that awareness while important, is only half the battle and translation of desire into action and results has now become the challenge of the hour. When progressive nations find that science and technology have become the means to both guns and butter, it would be patently incredible if we were to hesitate on investing in this vital activity. But if investment alone is the solution there would hardly be any serious problem in assuring that science and technology would get the nurturing it needs in our country, for when the question of necessity is established the allocation of funds could probably follow as axiomatic.

Perhaps, therefore, there is much more to the fostering of research and development than it meets the eye. The evolution of a policy in this regard cannot be expected to materialize without an examination of the many facets which comprise the term R&D, and the implications and interrelations of each with each other and the many other segments of national activity in the country which go into effecting the rate of increase or decrease in the gross national product. These all must therefore first be thoroughly examined.

The nature of research and development

R&D, stated very simply, is the means through which we endeavour to transform our resources into goods and services.

R&D, however, is not an activity which is of just one unique nature. From the unfolding of knowledge and understanding of nature to

innovations which could benefit the common man, is a process which has a series of activities that have come to be recognized, with good justification, as separate entities in the R&D process. These in my profession are currently recognized as:

Research. Includes all effort directed towards increased knowledge of natural phenomena and environment and efforts directed toward solution of problems in the physical, behavioral and social sciences that have no clear direct military application. It would, thus, by definition include all basic research and in addition, such applied research as is directed towards the expansion of knowledge in various scientific areas. It does not include efforts directed to prove the feasibilities of solutions of problems of immediate importance or time-oriented investigations and developments.

Exploratory development. Includes all effort directed towards the solution of specific military or other user problems, short of major development projects. This type of effort may vary from fairly fundamental applied research to quite sophisticated breadboard hardware, study, programming and planning efforts. It would thus include studies, investigations and relatively minor development effort. The dominant characteristic of this category of efforts is that it be pointed towards specific problem areas with a view towards developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters.

Advanced development. Includes all effort directed towards projects which have moved into the development of hardware for experimental or operational test. It is characterized by line item projects and programme control is exercised on a project basis. A further descriptive characteristic lies in the design of such items being directed towards hardware for test or experimentation as opposed to items designed and engineered for eventual use.

Engineering development. Includes all effort directed towards development programmes being engineered for use but which have not yet been accepted for procurement and operation. This area is characterized by major line item. Projects and programme control must be exercised by review of individual projects.

Operational systems development. Includes all effort directed towards Development, Engineering and Test of Systems. Programme control has to be exercised by review of the individual research development effort in each weapon system element.

This breakdown has an obvious logic; it is quite apparent that activity in any scientific sphere from the discovery of knowledge to its application and use, is a process comprised a series of events. A gradual migration takes place, as information matures, from science intensive to technology intensive activities.

The nature of activity in each of these events keeps varying, because the objective at each stage becomes different.

As a general observation, however, it is found that events in the first phase, i.e. in the 'Research' stage, are hardly amenable to control or programming, whilst at the other end of this activity spectrum the events are quite capable of being programmed on a schedule and must therefore be disciplined for economic results.

This leads to a significant conclusion—that knowledge once available, can be programmed for use.

In fact, technology is 'policy-prone' whilst science does not, of necessity, conform to the needs of the nation.

In formulating a research and development policy, therefore, we have first to discern in which part of the R&D activity spectrum our needs lie, and in each to what degree of urgency. In so doing we can deploy our energies and resources at least where they are needed most, without neglecting associated activities and hope, with some degree of certainty, for reasonable results.

The wholistic picture

The great problem in framing policy that can cater to current needs as well insure adequate growth to sustain future requirements, is the determining of relative values throughout all spheres of activity so that neglect is minimized and relative degrees of attention duly afforded as planned.

This of course is the crux of the problem. The arraying of values in the context of national needs is the only guide which can determine with any sureness the path which R&D, and for that matter all activity, can pursue.

What does this mean? It means that the lead must come right from the top, and the highest authorities in the land must invest time and thought on the priorities the country needs, and what is more important, the interrelationship amongst these priorities. The science and technology policy must not suffer from want of 'specificness'.

We cannot continue to have first a shortage of coal and then a swing to stagnation of coal because of wagon shortages. Then a surplus of wagon at places for lack of adequate track to take the increased traffic, consequent perhaps on lack of production of iron—not inconceivably due to lack of coal at the right time in the first place!

Where do we start?

Since science is international and competitive, the way in which it grows is dictated almost entirely by the present state of knowledge and scarcely at all by the wishes of nations or the needs of society. One has, therefore, no significant choice for a science policy except to support all ongoing research front activity to the very maximum of money that can be spent and of the talent that can be squeezed from the population.

A science policy as such therefore would appear impracticable. The indication then is that the policy should be to encourage scientific activity, from which would flow both science and technology. However, it does not happen that technology is a sort of fruit hanging from twigs of a scientific tree. Technology is another tree of a different sort, but both trees are necessary if either is to grow, and the delicate symbiosis that keeps the growth in step appears to derive from the educational process that supplies scientists with a feeling for the ambient technology, and technologists with a feeling for the ambient science of their student days.

Taking first things first, therefore, we have to ensure at the very start that we have the raw material to pursue science and technology. In this I would identify talent as a prerequisite and funds as only secondary. To

ensure adequate talent we must lay the foundation in our educational process. Without this any further attempts at bolstering our science and technology must crumble and remain a limped affair, perpetually reliant on outside assistance. For science to flourish—and if you look after science than technology, given adequate opportunity, would look after itself—we must nourish the intellectual stamina of the nation. This nourishment comes from the universities, and the universities must therefore be made the home of basic science and fundamental research. Research that is pursued by gifted and dedicated men working in universities with all the modern devices of research establishments available within the universities.

Next, to further sustain this scientific and intellectual output it is necessary to have institutes for advanced study for special fields of research, and even perhaps sophisticated programmes, for it is necessary to have this small and expensive group with high pay and prestige if society is to produce also the larger by-product of a supply of good teachers, doctors, engineers and other practitioners. Such activity would result in the ultimate in providing good education as well as new industries and new products. Such is the nature of 'spin-off' rather than any spectacular new discoveries. We have to produce somehow people who can assist us in arriving at the judgements, based on science and policies and an understanding of social values. They will be people who incorporate an appreciation for science and technology as a part of our cultural heritage, and be attained to the social, economic and political needs of our time.

The immediate problem

Having laid a source for sustaining scientific activity, we can turn to the problem of satisfying immediate needs.

Here we are concerned with a continuous mechanism for assuring that the fruits of science and technology are purposefully used for the economic and social Betterment of the entire country—not only the fruits of science and technology generated in our own country, but all that is available to the world at large—from the efforts of the world scientific community.

Legislation, outside of accepting the necessity for a type of activity can, in practice, hardly do anything more to ensure the actual functioning of any mechanism. The initiative and control of the activity envisaged must be given over to a competent body specifically constituted for the purpose.

In the USSR a state committee was set up for the purpose of coordinating scientific research in 1961. In the United States an Inter-Departmental Committee for Scientific Research was set up in 1947 and in 1962 the President of the United States entrusted his Scientific Adviser with the task of directing a central scientific and technological service. The UK has a Ministry of Science since 1959. The Federal Republic of Germany has a Federal Council for Scientific Question since 1957 and a Federal Ministry of Science since 1961. France entrusts its scientific problems to a Minister since 1958, and resorts to "concerted research drives" and scientific "round tables" to foster science. France in each four-year plan defines certain sectors where a special effort must be made say in molecular biology, brain disease, energy conversion etc. The USSR, I believe has no less than 40 institutions working on the desalinization of seawater, as an indication of the importance they give to this particular problem. Britain in fact has now created a separate Ministry of Technology, apart from their Ministry for Science, whatever the merits of such a move might be.

The first observation to be drawn from this is that science and technology have become the subject of urgent attention of most leading countries and we must also do likewise immediately. It would appear that today economic and scientific policies go together, for the only way in which we can spend more money in the words of Lord Todd*, is by increasing our gross national product, and to do this the distribution of our scientific and technological effort must be planned to provide the maximum stimulus to our economic advancement.

We need now to examine urgently and carefully our whole industrial structure and establish priorities. We must decide on the type of industry on which we should concentrate our effort—and this must be mostly technology oriented—establish priorities and set our policy accordingly.

We have to adopt perhaps the Russian, Japanese or even Chinese example, of immediately developing our engineering and craft skills in the technological area. It is necessary to develop this capability right-away, such as has been done by other countries in similar circumstances, by being able to copy and fabricate all the current equipment and instrumentation we currently use, entirely indigenously. This will give us a self-reliance of some order and enable us obtain the much needed experience we must have to take on larger projects.

Conclusion

In the light of such trends both in needs and thinking, the logical process which we must adopt to nurture and build our scientific and technological capabilities would be to:

(a) Expeditiously set up one competent and authoritative body to foster and programme science and technology in the country.

(b) Ensure that our educational system, particularly at the university level, is designed to produce adequate scientific talent not by merely outlining heavy syllabi, but by inducting competent and gifted men of science to guide and pursue significant basic research. To do this we should not hesitate to 'import' people and facilities, whenever required. The method of tax relief current in the USA for those who make donations to science and technological institutions might aid in the provision of funds for such work.

(c) Decide on what percentage of our GNP we should invest on R&D. This will depend of course, on our resources in money and manpower, but more so on the priorities in science and technology that are essential to assure the future of our economy. In the context of our dire needs perhaps it must at least be double our current spending and annually increased by again double the rate of increase in our GNP till we have obtained results.

(d) Decide the ratio of money we should spend on research as against technology. As technology is undoubtedly the need of the hour we must clearly invest much more in this sphere. For lack of a better figure perhaps the 1 : 9 ratio followed by other countries is a fair guide.

(e) In the area of technology, specific priority areas should be indicated and funds and facilities be accordingly made available.

*Address presented at Stanford University Shell Foundation Lecture, Dec. 14, 1964.

(f) The methodology of organizing this technological activity be laid down in general and work be pursued on a 'project' basis having a reasonable schedule of activity.

(g) The remuneration afforded to those engaged in scientific and technological work be brought on par with the best paid services, so that the status of scientists and technologists is elevated enough to draw the best talent into these fields.

(h) That accountability for project progress be always clearly laid down so that all credit or otherwise accrues to the individual concerned and not be lost in committees.

REFERENCES

de Solla Price, D. J., The Scientific Foundations of Science Policy, *Nature*, **206** (4981), (1965), 233–38.

Hollomon, J. H., A National Science and Technology Policy, IEEE Spectrum **1**, (8), (1964), 89-90, 95–97.

Krishan Kant, (ed.), Science Policy Resolution, Science in Parliament, **2** (1), (1964), 3–38.

Todd, A. R., Scientific Policy in Britain, *Science*, **149** (3680), (1965), 156–62.

United States of America, Department of Defence Instruction No. 3200·6. June 7, 1962.

Need for a Change in Manpower Policy

K. RAY
Directorate of Scientific & Technical Personnel
CSIR, New Delhi

In armed conflict or not, India has been under 'emergency' since independence. The fight against economic backwardness, illiteracy, malnutrition and various other ills that suffocate us has been going on for many years. The unfortunate armed conflict has only accentuated the gravity of the situation.

While the planning for industrial and agricultural development is being dealt with by competent scientists and engineers in this Conference, I would like to focus attention on the scientific and technical personnel who would actually be doing the jobs. They are the basic national resources. From them will emanate all the actions that are to be taken for implementing the various projects and schemes of development.

Much has been said and written about the scientific and technical manpower problems of the country. A good deal of statistical data is also available now. Statistics help understanding the problems and prospects. But, while dealing with human resources, a mere statistical approach is not the best method of meeting the situation. I sometimes feel that we have laid too much emphasis on 'number' which has led to a considerable degree of rigidity in our thinking. I shall therefore make some deviations from the orthodox method of number-matching in regard to the manpower problems.

Imbalance

We produce less of engineers and technologists compared to science personnel. The weightage is the other way round in industrially advanced countries. For every 100 science graduates in India, we have about 80 engineers at degree and diploma levels. In the USA, UK, USSR and China, the number of engineers is much larger than the number of science graduates. China is said to have engineers more than four times the number of science graduates. This may be construed as overemphasis. But, China may have her own reasons to do so.

It is quite clear that engineering and technological personnel who handle construction and production (direct economic spheres) must be required in larger numbers than science personnel. There is no hard and fast rule about it, but the experience of industrially productive countries shows that the number of engineers and technologists should be about 2 to 3 times the number of scientists.

Overstressing the production of engineering and technological personnel may weaken the scientific base. At the same time, it should be borne in

mind that engineering personnel and science personnel are not two distinct categories. Unfortunately, we have made watertight compartments for them in our mind. They are, in fact, complementary to each other and sometimes replaceable by each other to a limited degree. Here again our age-old convention has set the rigidity. A rational look will show that some of the work done by the engineers can also be handled by scientific personnel and vice versa. If we have flexibility of approach, we may have a better chance of utilizing both the groups in a more effective and logical way.

Demand

The educational and training programmes are based on the demand which has been assessed for the country. We have had experience that demands based on the number of probable vacancies or on probable work-targets or any other factor are not very dependable. For instance, the training of mining engineers based on coal production target for the Third Plan has been completely upset since the production target could not be reached. The actual production was short by some 30 per cent of target. The number of vacancies cannot be correctly forecast even for the next one or two years, let alone 10 or 15 years. Financial allocation, which is another controlling factor, may also be subject to considerable fluctuation in the next few years, depending on exigencies.

Difficulties arise in the first instance from the fact that the controlling parameters are not fixed, or even predictable. Secondly, the norms for manpower requirement are likewise unstable, if not fictitious. The norms are usually based on prevalent conventions in the country. In the engineering field, for instance, Governmental requirements of engineers are worked out on the basis of the value of the undertakings handled. There is wide departure in this norm depending upon whether the work is handled by public or private sector organization. The change of technology may also necessitate a change of norm. And we are not quick enough either to change the technology, or to change the norm when we have accepted a change in technology. Further, we place our scientific and technical incumbents according to our own convention and not necessarily to the intrinsic requirements. The 'surplus' or 'deficit' of personnel are therefore mostly based on conventional requirements.

Balancing

While the above situation makes it practically impossible to correctly assess the requirements in numbers, it gives a leeway to various types of adjustments. This, in fact, is a desirable position. The organizations handling scientific and technical personnel should find it an advantage to mould their human resources the way it is best suited for the organization and the country as a whole. When the personnel situation is flexible, adjustment possibilities should also be kept flexible. A rigid administrative system is totally unsuited for personnel adjustments.

Where scientific and technical talents are surplus in an organization, they should be deployed to organizations where they are wanted. We do not have such mobility. This creates simultaneously artificial shortages and surpluses of trained personnel. In the bigger interest of the country this is an expensive luxury.

Training of personnel

The universities and institutions of India produce technically educated personnel who are easily comparable to their counterparts in any part of

the world. But education and training are somewhat different. Every production organization, research institution or teaching department wants experienced scientists and technologists. Someone has to train them and give them the experience which every user wants. The fallacy is apparent. It is quite possible and very much desirable that scientists and engineers should be trained within the country and by the users themselves. Only then will trained people grow in the country.

This does not however mean that qualified scientific and technical personnel trained in an organization should not be permitted to move out of the organization. There will be a tendency on the part of the organization to hold back the scientific and technical personnel which it has trained. This is not a correct attitude in the larger interest of the country or for the organization itself. When all the organizations are training their personnel, it is natural to expect that most of them will stay on in the organization because of the nature of work that they are doing in the concern. There is no point in getting alarmed about an exodus of trained personnel from a particular organization or institution. Some of them may, however, like to change the concern for various reasons. Personnel should be free to remain or leave a concern. If some of them leave, others will come who have been trained elsewhere for a similar reason. There is, therefore, no reason to apprehend that there will be only a one-way flow of personnel. Making restrictive rules to prevent trained personnel changing their employment would only result in stagnation and frustration. It would also mean in-breeding which will prevent fresh talents from coming in. Interchange of experienced personnel in a free atmosphere of mobility will always help the organizations. The person trained in a particular field will move out to another organization only where the work in that field is available. There is therefore no loss of training in the national context. One will be replaced by another person in the same field and will come from another organization with fresh outlook. If all the organizations are afraid of losing personnel it means that all of them think that they will be without men. But where will these men be going ? They must be going from one organization to another and not vanishing into thin air. It is therefore not a question of loss but only a matter of mobility or interchange of personnel. This is healthy and desirable.

Under-utilization

Today we are more concerned about our inability to entrust our technical personnel with work commensurate with their scientific and technical competence. This is true of a quarter or a third of the qualified scientists and engineers. The problem is not one of number-matching but of quality matching. The quality of work entrusted should suit the quality of men. If three per cent of the engineers are wasted through unemployment, thirty per cent are wasted on inappropriate jobs. The wastage in employment is much more serious in magnitude than the wastage through unemployment. It points to the question of real demand we have discussed earlier. Persons with higher qualifications and competence who are doing incompatible work indicates employment on the basis of conventional demands. There is, therefore, a need for re-orientation of work in relation to the men. It is a matter of planning to divert the misplaced competent personnel to suitable positions either in the same organization or in other organizations where they can be effectively utilized.

Table 1—Trends in annual out-turn

Personnel	1940	1950	1960	1963	1965 (estimated)
Science graduates	2,700	10,000	23,000	29,000	32,000
Agricultural graduates	270	1,000	1,900	2,500	3,000
Post-grad. in science	450	1,100	4,000	5,000	6,000
Graduates in Engng & Tech.	620	2,000	5,700	9,000	10,000
Dip. in Engng & Tech.	1,180	2,500	8,000	13,000	16,000
Medical graduates	750	1,600	3,200	4,000	4,500
Vet. graduates	—	110	910	800	800

Table 2—Strength of scientific and technical personnel in India by the end of 1965

Category	Level	Approx. strength
Science	Graduate	260,000
Science	Post-graduate	65,000
Agriculture	Graduate	25,000
Engng & Tech.	Grad. & Post-graduate	100,000
Engng & Tech.	Diploma	140,000
Medicine	Grad. & Post-graduate	65,000
Medicine	Diploma	35,000
Veterinary Science	Grad. & Post-graduate	10,000

Table 3—Award of Ph.D.

	1952-53	1960-61	1962-63
Science			
All subjects	124	347	469
Physics	22	62	88
Chemistry	68	166	212
Mathematics	11	20	23
Statistics	—	5	4
Geology	1	9	21
Botany	10	45	70
Zoology	12	28	44
Engineering & Tech. (all)	6	30	n.a.
Medicine & Pharmacy	26	81	n.a.

Dynamic policy

If we do not bury ourselves in the conventional norms, we shall be able to adjust and readjust our work and men continuously as may be necessary. The development of a country is a dynamic process and the adjustment of personnel and work must be carried on intelligently and continuously. Where trained men are not available, they can be trained. Where trained men tend to be surplus, adequate jobs can be located. There will never be a perfect matching between work and men. But the gap must not continue to widen, it can be and must be adjusted continuously to bridge the gap and to promote the productive activities of the national economy.

Tables 1 - 3 reveal data on trends in annual out-turn, strength of scientific and technical personnel and Ph. D. holders respectively.

We have competent men and women, neither too few nor too many, yet we are worried about their shortages and surpluses at the same time. This is of our own making. We can iron it out if we take a rational approach to manpower problems based on work-personnel relationship rather than status-personnel relationship.

Suggestions for Rapid Growth of Industrial Research in India

S. L. MUKHERJEE
Sarabhai Chemicals
Baroda

Aid for investment in research

Phenomenal industrial and technological development during recent years in India, may be, to a great extent, attributed to the participation and technical collaboration of foreign companies. This had, no doubt, its own immediate advantages but, obviously, had also resulted in certain drawbacks, namely (a) in considerable drainage of national wealth outside the country and (b) in developing a sense of continued dependence on foreign know-how on the part of Indian entrepreneurs at the cost and sacrifice of strengthening indigenous industrial research.

In the context of the present stringent foreign exchange position of the country which is likely to be continued in foreseable future and in the light of the recent Government announcements that strict scrutiny of future foreign collaboration schemes will be made so as to find out whether indigenous technical know-how are available or could be made available for such purposes, a situation has arisen where industrial research units have to play a vital and positive role with respect to immediate import substitution and quick technological development programme. This requires serious thinking for not only enlarging and expanding the scope of the existing research and development activities within the industries in India but also setting up of new industrial research establishments involving considerable capital and revenue expenditure to the industries, so as to reduce dependance, as far as possible, on imports and foreign know-how, in furture.

Hence, it is felt that some immediate short-term relief should be provided to the industries, to create necessary climate and condition for investment in indigenous industrial research. With these objects in view, the following submissions are made:

(i) To encourage capital expenditure towards research and development activities within the industry, Government should allow 'write off' of such capital expenditure in the same year as it had been incurred, subject to a maximum of 10 per cent of profits and the balance according to the existing rule within 5 years. This relief may be applicable for an interim period of 5 years only.

(ii) Research establishments attached exclusively to industries also should be eligible to capital and revenue grants from the funds allocated and reserved for national research.

Canada's National Research Council finances 50 per cent of agreed research project cost for industries, the research being done by Canadian

industrial firms in their own laboratories for their own benefits. The firms themselves choose the projects and a committee assesses their suitability for NRC aid and it is stated that including other tax concessions for industrial research, a firm on an agreed project spends only about 12½ per cent of the project cost. This has been adopted for rapid industrialization in Canada.

It is also gathered that some percentage of national research fund is also employed similarly in research projects in industry in Italy.

At a recent conferenee of leading scientists and educationists, presided over by the then Minister of Scientific & Cultural Affairs, recommendations have been made to the Government to earmark 1 per cent of the national income for scientific research. It is strongly urged that our Government should adopt the same principle of financing industrial research establishments on projects of their own, for quick technological advancement.

Aid for technological development

It is stated that there are now 28 national laboratories and institutions run by the Council of Scientific & Industrial Research, where about 5,700 scientific and technical personnel are working in addition to about 1,200 research fellows and assistants engaged and financed by CSIR. It is estimated that the present annual expenditure budget of CSIR is over Rs 10 crores. Further, it is proposed to set up 10 more new laboratories and research institutions in the Fourth Five-Year Plan.

I believe, I can say, without much fear of contradiction at least from persons engaged in industries, that the contribution from the CSIR run laboratories has been rather meagre and negligible so far, towards technological advancement of the country, whereas if it is so desired, these laboratories could certainly render very valuable help towards technological advancement of the country by changing their outlook on industrial research programmes and by imparting technical know-how, on proper basis. It is not only our experience but also it has been the experience of many of our friends that so far processes developed by national research laboratories and lent to industries for development, are not in the form as it should be and considerable development work and expenses are required within the industries to adopt such process know-how into commercial practice. I believe, I will not be far wrong when I say that a belief is firmly gaining ground in the minds of the industrialists to feel hesitant about taking advantage of the process know-hows sponsored by national laboratories because they are not adequate, complete and perfect in the sense that they can be taken on the basis of operational turn-key job as available by foreign collaborators and consultants.

It is universally recognized that there is a big gap between the processes developed in the laboratory or in semi-pilot plant investigations and conditions required for development of technological know-how for its commercial adaptation. So long as this gap is not suitably and correctly bridged, imparting of process know-how from the existing set up of national laboratories will be imperfect and will not be readily accepted by industrialists. It must be borne in mind that the major part in industrial research constitutes development research, which is associated with technical activities on problems which are encountered in translating the research findings and other scientific knowledge into products and processes and which provides data on which a new plant could be separately designed or a existing one could be redesigned for establishing economic production.

It is also a recognized fact that money spent on development research in industries often amounts to more than three/four-fold compared to money spent on laboratory research. In my own opinion, this development research is practically lacking in the existing concept and set up of the national laboratories and unless serious and separate attention is paid to development research, the country is not likely to benefit technologically from the work carried out by the national laboratories.

Hence, it is suggested that an independent and separate Project Engineering and Development Institute be set up under NRDC having the following facilities:

(a) Multipurpose pilot plant set up
(b) Chemical engineering and development laboratory
(c) Drawing and design section
(d) Project engineering section

So that processes developed by the existing national laboratories could be taken up by this proposed institute, studied and further work done whenever necessary and complete project know-how be delivered on an operational turn-key job basis to the prospective investors. This institute should be considered as a pragmatic organization and should work strictly on commercial basis. So long as this is not achieved, thoughts should be given whether the recently established Engineers India Ltd, Delhi could temporarily function in this capacity or not.

Aid for new drug development

India has so far failed to make any significant contribution for developing a new drug in the pharmaceutical field. This appears to me to be mainly due to lack of adequate facilities in the country for quick screening, pharmacodynamic and clinical evaluation, on synthetic compounds or products from natural sources, and also due to want of suitable coordination between the chemists and the pharmacologists and clinicians. It is well known that in synthetic field, 3/4 thousand compounds or more should be screened before a new drug could be discovered. Besides, after screening, if any compound appears to have potential pharmacological properties, detailed toxicological studies and clinical evaluation of the compound is necessary, which are both time and money consuming factors. In India, there is hardly any establishment existing at the moment, either with the pharmaceutical industries or with the Government which could undertake large volume of screening of new compounds and detailed pharmacological and clinical evaluation programme on a quick turnover basis, which are essential for development of a new drug.

Quite recently, attempts have been made by the Pharmaceutical and Drug Research Committee for establishing a few screening centres in the country on no fee basis, which would undertake outside screening work with certain stipulated conditions of having to disclose the identity of compounds prior to screening, which, I am afraid, are not helpful to private pharmaceutical firms. In addition, the time taken for such screening work is usually very long to derive immediate practical benefits. Hence, to facilitate development of new drugs, it is suggested that a separate screening, pharmacological and clinical evaluation centre be established by the Government wholly on commercial basis for expeditious screening and pharmacodynamic studies on new compounds or products. This centre must have adequate facilities of evaluation and screening of at least 5,000 compounds annually from private, university and other sources, strictly on fee basis and priority assigned in the order as these are received.

Some Aspects of the Organization of Research

B. RYE
ICI (India) Private Limited
Calcutta

Introduction

The development of a nation in the modern age rests on the skills of its scientists and technologists as much as its administrators. This is true of the advanced as well as the advancing countries and throughout the world a great deal of attention is being paid to the education of men who can discover and apply knowledge and techniques. New universities are founded, old ones expanded and public expenditure is multiplied many times in their support. A growing weight is given to the physical and socio-economic sciences in response to the stimulus from industry and the environment it creates. And as trained men spread through industry and government there is more and more deliberate application of logical thought and experimentation in every sphere of activity. In its more formal shape it is undisputably research, but it is as well to recognize that the term nowadays has a much wider connotation than formerly. The activities in the research institutions within industry and the independent institutions sponsored by industry is often very different from the traditional picture conjured up by the word 'research'. Yet these institutions and government laboratories are playing an increasingly important and in some countries a dominant role. Their various functions are often ill-defined and overlap but in this note we shall draw attention to some of the main features and examine briefly the implications for the organization and development of research in India today.

Role of the universities

At the outset it is worth stating explicitly that research is indivisible. The distinction is sometimes drawn between pure or basic or fundamental research on the one hand and applied research on the other, and this indeed may be perfectly valid with reference to the objective in view. Often, however, it is implied that pure research is the finer pursuit. Applied research, it is suggested, is somehow inferior and an unworthy subject for top class intellectual endeavour. The persistence of such an attitude is noticeable particularly amongst the impressionable and brighter young graduates when talking to them about their future careers. It is partly responsible for diverting some of the best of them to a post-graduate progress from one minor academic post to another until at the age of thirty-three or thereabouts when they look for a more permanent and lucrative job in industry they find that despite their academic honours, undoubtedly well-earned and deserved, they are without the background, experience and outlook for picking up the threads of an industrial career appropriate to

their age and seniority. The readiness to discriminate between pure and applied perhaps stems from an old fashioned and never influential tradition in the English universities which are in any case now much closer to the Americans and Germans in regarding it as pointless so far as the intellectual approach and the method are concerned. Naturally enough, most raw graduates fired with the excitement of their subject will think of university research and of emulating their professors' achievements. It has yet to be demonstrated to any real extent in India, and here industry has to make some constructive moves, that the opportunities in industry for discovering and applying new knowledge are just as exciting and demanding of intellectual and manipulative skill. And if on the whole the philosophical content is not as great there is ample compensation in the satisfaction of making a contribution to the immediate social and economic advancement of the community. In a modern industrial society three out of four graduates leave university to enter industry. To embark satisfactorily on their career they ought to have the basic skills and knowledge of their discipline and a concept of how they might play an effective part in society. Industry and the universities have to come much closer together than they are at present in order to develop the skilled manpower of the nation to a fuller potential.

The division of effort between teaching and research in the universities is closely related to our main theme. It is tempting to stress the importance of teaching and the need for the universities, the apex of the educational structure, to turn out administrators, scientists and technologists in large numbers, eventually to become leaders in all walks of life. But teaching at this level invariably suffers unless it is associated with the seeking out at the earliest possible age of that small minority of people who promise highly creative ability and interesting, encouraging and stimulating them so that their natural talents are formed and sharpened through an acquisition of sound background knowledge and a thorough mastery of experimental and theoretical techniques. Clearly this can only be done where research is actively extending the horizons of human knowledge. However, the expansion of the student population, particularly in the older universities has overborne staff and teaching facilities to such an extent that the cultivation of this important minority has become almost impossible and the growth of a fine research tradition severely cramped. Without it the rest of the work of the university suffers and makes the policy of numbers before quality highly questionable. We touch on this old dilemma so as to highlight the need for a reassessment when shaping a plan on a national scale for promoting research. Progress will depend, amongst other things, on a steady flow of people trained to a pitch where they can pursue research profitably in one or other of its many guises. As well as a few of the topmost rank there has to be a growing number of rather more ordinary people imaginative, competent, energetic and aware of the social and economic aspect of their work, the professional body which will bear the brunt of the load. Without them, the universities themselves will suffer and it will be difficult to carry research into industry and government laboratories. As we shall illustrate, it is only possible in the environment of industry, commerce and administration to get a proper measure of the economic compulsions affecting the definition and solution of many problems.

Role of the government laboratories

Whilst we must accord every consideration to India's own needs and circumstances, the history and present status of the Government laboratories

in other countries can offer a useful insight into the best way of developing these institutions which are vitally important to the national economy and to defence. The parallels between the mixed economy of India and of the US and the UK are close enough to show in broad outline where government laboratories and research institutions are likely to contribute most effectively. Probably it will change somewhat as the structure of research develops throughtout the country but it is clear that there are certain specific functions to be discharged. Science and technology affect the national interest so closely that government cannot be without its own source of informed advice on the organization of scientific effort throughout the country and a means for objective evaluation of scientific matters which concern it based upon thorough and penetrating analyses of problems and situations in circumstances where there can be no conflict of interest such as might quite legitimately arise in an academic or industrial institution. This does not preclude the development of close associations with non-government research. Indeed the indivisibility of research requires contacts to be fostered to get the swiftest connexion of cause and effect. Security is troublesome, particularly in matters of defence. If ways can be found around the difficulties it presents, there will be many opportunities for fruitful collaboration between government and industry over the building up of defence materials from indigenous resources. An example is the substitution of plastic materials for metals, especially non-ferrous metals and alloys most of which are imported. In industry there is a store of valuable know-how and experience of manufacturing and fabricating plastic materials that can be brought to bear once the problems are clearly defined and stated. Looking at it from industry's point of view, government is in exactly the same position as any other customer whose requirements have to be studied and met as well as possible by employing materials and equipment that are readily to hand. In this kind of situation industry is fast learning the benefits from close technical liaison between customer and supplier and it is a great stimulus in the present circumstances to the growth of research facilities within industry.

Another principal field of activity for Government laboratories is the study of national resources of materials and energy. The interest of industry in this work and its results must obviously be profound, and here again the benefits of collaboration are enormous. The roles are now reversed and industry is the potential customer whose opinion must be sought if requirements are to be matched as nearly as possible to the sources of supply. The effective use of the country's vegetable oils is a case in point. It is quite possible that non-edible oils can be found that would satisfactorily replace edible oils used in resin manufacture with consequent benefit to food supplies. But more is involved than merely doing a few tests on various samples. Not only has an oil to be acceptable to a paint manufacturer on technical grounds. Before committing men and facilities on a considerable scale to working out a new process and product (there is a tendency outside industry to underestimate what this involves) assurances will be sought on the price and availability of the new material in commercial quantities and consistent quality. Without them the risk of failing to make and market a new product on a commercial scale would probably be too great to warrant the research effort. Equally, the vegetable oil trade keeps to the products for which there is a demand. There is little incentive to promote the collection and standardisation of a new material unless there is a firm offtake in prospect. The example is chosen, of course, to display in a simple form free of the confusing detail

of most real situations the latent difficulty of developing the use of a new raw material or a substitute for an old one.

The study of resources is closely allied to the work of standardization and the need for establishing national standards, providing samples of ultra-high purity compounds and measuring and evaluating their physical and chemical properties to provide national reference data. This activity is an essential complement to the work of the Indian Standards Institution whose principle task is to arrange for the drafting and promulgation of standards acceptable to suppliers and users based on fundamental physico-chemical data and proved test methods. A cursory glance through the Standards suggests that a considerable use is still being made of data and methods from abroad and while this might be expedient for immediate commercial purposes it cannot satisfactorily serve the ultimate aim of a consistent corpus of national standards and specifications.

In connection with the problems mentioned later faced by smaller firms in building up their research activity the possibility is worth exploring of the various government laboratories providing an analytical service for industry. The equipment and skills requir d in the government laboratories for work on standardization could then be used to the fullest extent. There is no reason why such a service could not be developed on a full commercial basis with an adequate charge made to cover expenses. The demand from industry for a reliable and expeditious service would probably be very strong. This leads on to the larger question of how far more complex activities such as sponsored research might be handled in government institutions and independent private laboratories. To obtain a clear view of this it is useful to summarise the main characteristics of the kind of research work industry requires.

Role of industry

A dominant feature of the industrial scene is the rate of discovery of new products and the development of novel and more economic production processes. The work in many countries of universities and government establishments has been invaluable in consolidating and extending the general understanding of chemical and physical phenomena, in providing new research and analytical tools without which modern advances would have been impossible and in a limited number of cases providing the initial leads to new products and processes. Nobody would wish to underrate these contributions but the fact remains that a very high proportion of the completely novel chemical products and chemical processes have resulted from the work of scientists and technologists throughout the world operating inside the chemical industry itself. The polymer and synthetic fibre fields offer many well known examples. The fact that they are now made in very large quantities at low prices is due to the discovery and development in industrial laboratories of entirely new processes such as the catalytic air oxidation of aromatics to acids and the direct oxidation of olefins to aldehydes, oxides and esters. In the vital field of nitrogenous fertilizers, the discovery and development of the process for steam reforming hydrocarbons to produce ammonia synthesis gas has opened up vast new possibilities. In addition, research in industry aimed primarily at its own commercial objectives has contributed greatly to the body of scientific knowledge. Colloid science and the control of crystal habit, for example, have been developed very largely through work in industrial laboratories. But all this is to stress the similarity between work done in industrial

laboratories and elsewhere. It calls for just the same ingenuity and skill as any other form of research and involves much more so-called fundamental work than is commonly imagined. The special characteristics lie in the manner of defining and tackling the host of related problems that an embryo project presents. An industrial concern knows the sort of future projects which on commecial and other grounds will fit in with their operations. It knows the gaps in scientific and technical knowledge which stand in the way of these projects and can therefore direct the more basic or exploratory research towards filling them. When a promising lead to a new product or process is found, a deliberate concentration of resources can be brought to bear on all aspects—scientific, technological, economic, commercial and financial. Inside industry all can be tackled simultaneously or in an optimum order by research, development and all other appropriate sections working together so as to ensure either speedy establishment of a product or process, or alternatively early recognition of failure with minimum wasted effort. Outside industry the necessary intimate knowledge of the whole business field is lacking and makes impossible the organization of an integrated attack of this kind. The future growth, diversification and productivity improvement in industry will increasingly depend on its own internal research effort. Academic research will continue to extend the range of fundamental knowledge, and there will be wide scope for the government laboratories but in the main, and certainly so far as the chemical industry is concerned any form of research for industry can never be an effective substitute for research carried out inside industry. In the present context of foreign exchange shortage and the need for more self-sufficiency this point must be strongly emphasized.

The basic difficulty is probably one of size. Unless a firm can support a research section that is viable and productive there is danger of wasted effort. Most of the public sector undertakings are big enough and potentially profitable enough to be able to afford the cost. The building up of research groups within the public sector industries even to the extent of depleting the trained manpower resources in the government laboratories might be a constructive move at the present juncture to initiate lively research within industry. In the private sector a few firms are also big enough, and some progress has already been made. Since the financial outlay is usually made well in advance of any return, some incentive by way of additional tax relief would be a stimulus to further development. The majority of firms however are too small. Unless there are enough men and equipment success hardly ever comes on time to be profitable. Management and researchers are discouraged alike and disillusioned, and the right atmosphere for research, if it ever existed, is quickly dispelled. A possible way out is through cooperative research associations and institutions undertaking sponsored research. Enthusiasm for the widespread adoption of this course has to be tempered with a knowledge of the particular difficulties such organizations face in other countries over the ownership of know-how and patent rights. In practice their work tends to be limited to properties of materials, specifications and testing methods, the extent to which they tackle research into products and processes depending a great deal on the structure of each association. However, even in the smallest company a start can often usefully be made to put operations on a technologically more satisfactory basis. The introduction of in-process sampling and testing of materials and components can go a long way towards quality and making it more consistent. Many large and imposing industrial research organizations have had humble beginnings as works test laboratories and a movement amongst all firms to better

sampling and testing techniques not only has immediate economic consequences that flow from standardization and consistency but on a nation-wide scale it creates grow ng points around which research groups can be built as opportunity presents itself.

The larger firms whose size enables them to support viable research groups are faced with a rather different set of problems and probably an embarrassing range of topics for investigation. Precise definition and careful selection is important in order to prevent effort becoming too dispersed. And frequent review is essential to ensure early termination of unpromising lines. This means that research in an industrial setting cannot be treated as an isolated and separate activity. It has to be closely involved with and become a part of the management function. A difficult economic situation such as we now face at least has the effect of clarifying many of the issues at stake and pointing out where research effort must be concentrated. When this is done to the maximum extent and the effort applied at the right points even meagre research resources achieve surprising results as the Japanese have so well illustrated. Although a high level of scientific spending is closely related to a high level of national output per head it is not necessarily linked to a high rate of growth. Buying the inventions of other countries may often be less expensive and just as remunerative as original research. The US and UK combine a high level of expenditure with a slow rate of growth. Japan does just the opposite by a judicious mixture of home invention and foreign know-how, and even though foreign exchange is limited the policy should be to get the optimum mix for India as well. Industrial research must be international in outlook and based on competition and exchange with the best in the world. Just as India has to balance her trade in commodities and services with the rest of the world, so also in technical know-how. It is in industry where this valuable and saleable asset is created, and in the overall national pattern of research, industry should build up to the dominant role, enjoying the major share of men and facilities.

Coordination between Research and Industry

S. C. DOSHI & W. W. ROBERTSON
Indian Aluminium Company Limited
Calcutta

In analysing the present situation, the country has well-staffed, and well-equipped research laboratories which are not being used to best advantage by the developing industries. There seems little doubt that the rate of industrial growth could be accelerated and our dependence on imported materials and technology lessened, if ways can be found to improve this situation. Without trying to localize the cause of this, there appears to be a serious communication block between the two parties.

In the following, specific examples of collaboration between various research institutes and the Indian Aluminium Company Limited are described. Several suggestions are offerd (of which a summary follows) to improve the liaison between the national research organizations and industry.

1. *Publicity*—The national research organizations should make greater efforts to acquaint the industries of the type of services they are able to offer.

2. *Technical service*—Consideration should be given to establish technical service departments in the research organizations. These would be staffed by qualified people who would spend considerable time visiting industrial establishments and act as a dynamic liasion between the two groups.

3. *Procedures*—The administrative procedures for allocation of industrial research problems to the national laboratories should be simplified.

4. *Exchange of assignments*—Procedures should be set up to permit research scientists to spend some time in industrial assignments.

5. *Industrial management*—More attention should be paid to research in industrial management.

6. *Consulting services*—There appears to be scope for special consultancy services capable of rapid action on certain types of industrial problems.

7. *Research by universities*—The American practice of assigning industrial technical problems to universities seems to have merit.

Introduction

Though planning, as a concept for the economic and industrial development of the country, was accepted after Independence and coordination between research and industry was emphasized at every stage, we feel that this emphasis has not so far shown the desired results. It therefore becomes

necessary to re-emphasize the importance of establishing systematic and effective coordination between research and industry with a view to achieving the industrial targets that we have set before us in this country. Everyone assembled here is aware that close liaison between research and industry is a most important means for achieving rapid industrial growth with a minimum dependence on outside agencies and at minimum cost. The following extract taken from the summary of the Third Five-Year Plan, page 168, Planning Commission, Government of India, speaks eloquently on this subject.

"The importance of ensuring speedy and extensive utilisation on a commercial scale of the results of scientific research has been stressed for several years. The National Research Development Corporation was set up with the object of exploiting the results of laboratory research for commercial production. However, a large proportion of the inventions made in the country still remain to be exploited. Intervals between the time when the results of laboratory research become available and their wider application, are at present considerable and there is need for more effective action. The factors which have hindered rapid utilisation of the results of research appear to be lack of pilot plant facilities and of design and fabrication facilities, inadequate liaison between industry and research organisation, insufficient attention on the part of industry to the urgent need to secure indigenous production to replace imported articles, and inadequate co-ordination between licensing policies and programmes for the development of research. Facilities for design and fabrication of pilot plants are now available in much larger measure than before, and such deficiencies as exist will be made up to a considerable extent during the Third Plan. The other aspects mentioned above call for a new approach. It is crucial that there should be a close association between research workers and individual industries, fuller knowledge and greater understanding on their part, both of the problems requiring solution and of the results obtained, and adoption by such industries of carefully considered schemes for the utilisation of the results of research, replacement of imported items by indigenous manufactures and achievement of higher standards based on research undertaken within the country. In particular, Development Councils and other organisations concerned with different industries should regard such schemes as an essential part of their programmes of development during the Third Plan. They should ensure that research workers receive the necessary assistance and facilities from industrial plants and from executives and engineers in different industries".

At the outset, it should be clear that the fundamental objective of any industry is to produce a quality product at the minimum cost and for fulfilling this objective, research plays an important role. Technological improvements to achieve higher production with the available resources is of paramount concern. In this country, industry is to a large extent in its formative stage and tends to be preoccupied with the short term problems of process development and the attainment of acceptable efficiencies. In many cases industrial concerns have not reached the stage of maturity at which they can provide themselves with their own research facilities. It is therefore appropriate that it has been seen fit to establish rather complete research laboratories in all of the technical fields of importance in the country. One should pay tribute to the early planners who foresaw the need for these facilities and took the necessary steps to provide them.

The fact that this meeting is being held is testimony that there is a communication problem between industry and the laboratories. Thus

available facilities are not being utilized to their best advantage. It seems pointless to try and fix the blame for this situation on one party or another. However, this meeting should be considered fruitless if it does not come up with some positive suggestions as to how the overall situation can be improved.

Examples of successful collaboration

We, in Indian Aluminium, have not had frequent opportunities to work with the research institutes. Much of our technical information has been made available to us by our foreign collaborators. Each of our plants has an active development section which concentrates on the short term problems of process development with special attention to local conditions. Yet occasions have arisen when we have used available research facilities to advantage, and examples are cited below.

Development of composite aluminium primer by RRL, Hyderabad. The main objective of this study was to demonstrate the relative advantages of an aluminium-pigmented primer over the traditional red and zinc-chrome-iron oxide primers.

The CSIR was approached with the proposition that a scheme of exposure tests should be carried out at various centres in India to evaluate the comparative performance of aluminium-zinc oxide primer and the conventional red lead and zinc-chrome-iron oxide primers. The Regional Research Laboratory, Hyderabad accepted the scheme as a government research project sponsored by Indal. The scheme comprised five-year trials of the primers on exposure racks located in Hyderabad, Madras, Kanpur and Calcutta. Observations recorded after five years' exposure at the various centres showed that the composite aluminium-zinc oxide primer had the maximum durability followed by red lead and then by zinc-chrome-iron oxide.

This primer is now accepted by industries and the Indian Standards Institution and will currently result in a saving of foreign exchange of about Rs 7 million per year. We would like to point out that without the cooperation of this research institute, this project would not have succeeded.

Development of a process for pyrotechnic powder. Another example of successful coordination between an educational institution with some research facilities and an industry is provided by the successful development of a process for the production of pyrotechnic aluminium powder. In 1953, an initial laboratory investigation at our Kalwa Works, near Bombay indicated a good possibility of converting aluminium filter cake into aluminium powder of pyrotechnic quality. Trade inquiries indicated that this powder, mainly used for the manufacture of fireworks in this country, was imported to the extent of nearly 200 tonnes in 1953.

After the initial investigation, it became necessary to carry out some detailed studies for which the necessary facilities and equipment were not available with us. We approached the University of Bombay, which had the necessary facilities at their Department of Chemical Technology, Matunga, Bombay, and they readily agreed to make these facilities available to us for our test work. The work was carried out successfully by our own technical personnel and based on these experimental data, a 200 tonne per year pyrotechnic powder plant was designed and built.

Possible subjects for future study

We are at present in correspondence with National Metallurgical Laboratory, Jamshedpur, on two problems of considerable importance, where we are hopeful that useful collaboration will result.

Refractories for alumina kilns. The refractories in alumina calcining kilns have to resist very rigorous thermal and mechanical stresses. These were formerly imported but are now available of indigenous manufacture and difficulty has been experienced with premature failures. The assistance of NML is being sought to find means of improving the service life of these refractories.

Bauxite beneficiation. One of the important cost items in the aluminium industry is the caustic soda consumed in the refining of bauxite. The problem is particularly acute in India where the price of caustic soda is considerably higher than the world price. It is theoretically possible to reduce this consumption significantly by beneficiating the ore to reduce the reactive silica content. We consider this a problem of considerable importance not only to ourselves but to the industry at large and which is particulary suitable for study by the NML.

Examples of less successful collaboration

These examples should not create the impression that it is always possible to achieve successful coordination between research and industry. We had our share of disappointments as illustrated by the following examples:

(i) At our Alumina Plant near Ranchi, vanadium salts accumulate over a period in the Bayer liquor. The NML expressed interest in the recovery of V_2O_5 from this vanadium sodium salt in November 1963. Unfortunately due to lack of closer liaison between the two organizations the experiment has got bogged down. It is essential in our opinion that when a research organization takes up an industrial problem, closer liaison is maintained with the industry concerned. This will generate the confidence in the industry and will also provide opportunities for the industrial utilization of such work originating from the research organization.

(ii) At times our technical talent, resources and time are wasted on technical problems which have been successfully solved by other developed countries and the results are easily procurable. Some time back the Central Electrochemical Research Institute, Karaikudi, requested us to help them to construct a pilot cell for the electrolytic production of aluminium metal. The commercial aluminium process has been operating in India for the past 22 years and the fundamental technical principles involved are well known. It happens to be a process which does not lend itself well to study on a small scale. Such an installation would be very costly. Considerable information is available in the literature on the process and it is very doubtful if such a project would yield information of practical value to the industry in the country. We therefore felt it our duty to discourage such an endeavour.

(iii) Another example is the case of the aluminizing of steel wires and strips. A process has been established for this purpose and also licences for its exploitation issued to number of organizations. The fact however remains that for one reason or the other it has not so far been commercially exploited. Possibly a better follow up would have produced results.

Desirable orientation for research & development work

This brings out an important aspect, the advantages that can flow to underdeveloped and developing countries by utilizing the technology already successfully developed in industrially advanced countries. These developing countries can save immense effort, precious time, scarce technical talent and shy capital by making use of the technical results already available in the industrially advanced countries. Developing countries like India should therefore concentrate their efforts on technical problems, the solutions of which are either not easily procurable or are not known and and which have possibilities of immediate industrial application or are peculiar to the local combination of resources and economic conditions.

The subject of effective coordination between industry and research has been the centre of a certain amount of controversy between research institutions and industrial undertakings, both blaming each other for the lack of sincere interest. It is common to hear of the industries heaping blame on the research organization for assuming a superior, deprecating attitude towards the practical and profit oriented 'saving a paisa' problems of the industries and in the same vein research organizations accusing the industry of not showing enough interest or lacking confidence in bringing their problems to them. Probably both sides have to share the blame but little will be accomplished in trying to assign responsibility.

In this regard, one of the major areas of difficulty is the negligible or even non-existent channels of communication and cooperation between educational institutions with research facilities together with other research organizations and industrial undertakings. At the university or technical institute level the motivation tends more towards the 'Engineering Science' area without any real appreciation of the functions of engineering innovation, design and synthesis. The teachers and research workers who staff these institutes have,understandably, very poor or at best a hazy knowledge of the conditions obtaining in industry where operating results play a more important role than the publication of research papers and academic recognition. On the other hand, people entering such institutions from the industry (which is very rare because of the better emoluments in the industries) both as teachers and research workers become, generally, very rigid technologists, lacking appreciation of the role of 'engineering science' approach towards the logical solution of technical problems.

Thus, a continuous interchange of ideas between the research and educational institutes and the industry assumes a key role in this context. Although the different technical professional societies like the Indian Institute of Chemical Engineers, the Indian Institute of Metals etc., with members drawn from the industries as well as the research and educational institutes serve to achieve this to some extent, a more vigorous and direct approach is probably called for at present.

Suggestions

The following suggestions are offered for consideration to improve the present situation:

(a) Better Publicity of Research facilities: The fact that the research facilities are not being used to the best advantage can in part be due to a lack of awareness on the part of the potential customers as to what facilities are available. For this purpose a large volume of highly technical research papers is not the answer. A more pragmatic approach is required which

can convince the industrialist that the research organizations can provide services useful to him. The idea of commercial advertising may be objectionable to many research administrators yet in order to achieve the desired end result it may be necessary to adopt some such measure.

(b) Technical Service Department: It may be useful for the research organizations to establish'technical service departments' such as is done in some other countries. These departments would be staffed with full time employees who would act as a personal link between the laboratories and the appropriate industries. They would spend considerable time travelling and visiting industries, and strive to become familiar with the industrial problems and to determine areas where the research institutes could best serve.

(c) Simplified Procedures for Allocation of Industrial Problems: The procedure for the allocation of industrial problems to research institutes should be further simplified to remove hindrances and procedural red tape. Industries role should be to define the problem in specific terms, indicating the results sought. In most cases it will be necessary for the research worker to make an on the spot study of the problem to become more familiar with the economic and practical aspects.

(d) Industrial Assignments for Research Personnels: Another step to make our research workers 'industry oriented' is to have them on a regular basis deployed for some time every year in industries, so that they have an opportunity to observe for themselves how scientific principles and technical knowledge are applied in industry. This calls for the shedding of the superior airs which academically oriented personnel put on when they occasionally visit industries. On the other hand this will enable the industry to locate right research personnel and research organization to handle their technical problems. A good dispersion of research personnel into industry on a regular basis is therefore necessary to change the fundamental approach of research workers in this country.

(e) Consulting Services: The need also exists for developing the aspects of 'Consultancy Services' by research organizations or as a private venture by a group of qualified research workers. This will help to some extent the existing vacuum in the areas of project evaluation and process development—areas in which facilities in India are sadly lacking.

(f) Industrial Research by Universities: The American practice of assigning industrial technical problems to universities deserves special attention. The industry assigns such problems to universities and bears all the cost of investigation. A number of research workers work on these problems in close cooperation with the sponsoring industries. When the problems are successfully solved, the findings are made available to the sponsoring industries. Thus in this system, a three-fold objective is achieved. The industrial technical problems are satisfactorily solved; the research workers engaged on these problems get their higher academic qualifications by taking up such technical problems for their research assignments and the universities gets the credit as well as the funds to support itself. It is suggested that this practice should be adopted in this country. Most of the work done in the research organizations are rarely of immediate application in our industry and therefore when we are short of time, money and talents, it is necessary that these meagre resources should be husbanded in such a way that it produces some tangible results within the minimum span of time.

Conclusion

In conclusion, we would like to say that though industry, research and the government have accepted in theory the need for close liaison and cooperation between research and industry, this has not as yet been realized. The situation has become really crucial due to the two recent aggressions this country has faced, which have brought home to us our utmost dependence on outside help. We should consider this critical situation as a blessing in disguise and make every effort to take full advantage of this crisis for the good of the country as a whole. We have the necessary talents and resources, but we seem to lack the will, confidence and coordination. With the fast expansion of industry envisaged in the Fourth and Fifth Plans, there should be no dearth of opportunity for developing a technology of our own comparable to that of any advanced country of the world, provided our resources are harnessed in the right manner and in the right direction.

Price : Rs. 6.50 Sh. 13/- $ 2.00